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Trimble County Generating Station, Louisville Gas and Electric Co., Kentucky. Technical Appendix

Environmental Protection Agency, Atlanta, Ga Region IV

Feb 78

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LG&E proposes to construct a 2340 megawatt coal-fired steam electric generating station at Wises Landing, Kentucky, Ohio River mile 571. A 1000 acre site for structural and pond facilities is needed as are two ajacent ravines (1300 acres) for solid waste disposal. Associated transmission facilities are also proposed. Major Federal actions for the project are issuance of new source NPDES Permit from EPA and a section 10/404 Construction Permit from the Army Corps of Engineers. Air Quality and scrubber technology are the major issues. Aesthetic and secondary impacts to the river valley are also significant issues.

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PB 280 933

DRAFT

ENVIRONMENTAL IMPACT STATEMENT

TRIMBLE COUNTY GENERATING STATION

TECHNICAL APPENDIX

UNITED STATES
ENVIRONMENTAL PROTECTION AGENCY
REGION IV
345 COURTLAND STREET, N.E.
ATLANTA, GEORGIA 30308

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DRAFT ENVIRONMENTAL IMPACT STATEMENT
TRIMBLE COUNTY GENERATING PLANT
SUPPORTING REPORT

TECHNICAL APPENDIX

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TECHNICAL APPENDIX

TABLE OF CONTENTS

Number		Page No.
I	ADDITIONAL ALTERNATIVE SITES	TA-1
II	CONDITIONS APPLICABLE TO INTAKE STRUCTURE EVALUATION	TA-9
III	DATA AND ASSUMPTIONS FOR SOLID WASTE DISPOSAL CALCULATIONS	TA-11
IV	ESTIMATED ASH AND SLUDGE FORMATION	TA-17
V	ACOUSTICAL DATA ACQUISITION AND REDUCTION INSTRUMENTATION	TA-21
VI	MONTHLY RECORD OF FISHES COLLECTED FROM THE OHIO RIVER AND CORN AND BAREBONE CREEKS, JULY-OCTOBER 1975, TRIMBLE COUNTY GENERATING PLANT SITE	TA-25
VII	REPORT ON THE SEISMICITY OF THE TRIMBLE COUNTY SITE	TA-33
VIII	NUMERICAL DISPERSION MODEL STUDY OF TRIMBLE COUNTY COOLING TOWER PLUMES	TA-65
IX	DAMES & MOORE SALT AND LIQUID DRIFT DEPOSITION MODEL DESCRIPTION	TA-135
X	COOLING TOWER BLOWDOWN DISPERSION STUDY	TA-143

TECHNICAL APPENDIX I

ADDITIONAL ALTERNATIVE SITES

Central City Site

This 750-acre site lies near Central City in Muhlenberg County, Kentucky. The main advantage of this site is its proximity to a coal supply and cooling water from the Green River. However, substantial economic disadvantages are associated with transmission of power to the Louisville area. Two separate, double-circuit 345-kV lines would have to be constructed for a distance of 140 to 150 miles (two separate lines are needed to maintain transmission system reliability). Costs of construction for the lines are estimated to be $175,000 to $200,000 per mile, and a right-of-way approximately 250 feet wide would be required. In addition to these high initial capital costs, power loss costs over this distance would be great, and there would be high maintenance costs. Further, the environmental costs of these lines would be incrementally more severe than shorter lines. Local coal reserves near the plant also may not be available to the Applicant for the entire operating life of a plant in this location.

Chenaultt Site

This site is located on the Ohio River flood plain (River Mile 693) near Chenaultt, Kentucky and across the river from Derby, Indiana. Its chief advantages are availability of cooling water from the Ohio River, barge transportation of coal and other materials, and nearly level topography. A chief disadvantage is the long transmission distance; it is approximately 12 miles to the nearest point on an existing 138-kV line and 32 miles to the 345-kV line at Mill Creek. The latter routing would involve two Ohio River crossings and a crossing over part of Indiana. Lack of good highway and rail access, limited extent of land suitable for plant construction (approximately 700 acres), and poor site drainage are also important disadvantages.

Coopers Creek and Moreland Creek Sites

These two sites are flood plain areas in close proximity to each other along the Ohio River in Trimble County, Kentucky (between River Miles 561 and 565). Each has approximately 400 acres of nearly level land bounded by high bluffs comprising Pleasant Retreat Ridge. They are approximately 3 to 7 miles downstream from Madison, Indiana. The chief advantages are availability to Ohio River cooling water and barge transportation and proximity to the existing transmission corridor. Disadvantages are their proximity to other large air emission sources, including the Clifty Creek Power Plant. The added impact on air quality probably would cause substantial public opposition. The area of suitable level land at both sites is also limited and probably not adequate for a 2,400-MWe facility.

TA-1 and TA-2 are blank.

Fisherville Site

This is an inland site located in Jefferson County on Floyds Fork of the Salt River between Fisherville, Kentucky and Interstate 64. The Southern Railroad line, located at the south end of the site, would provide coal transportation to the site.

The chief disadvantages are the prohibitive Air Quality Maintenance Area designation of Jefferson County for sulfur dioxide and particulates. Assuming that air quality were not restrictive, there remain a number of other important disadvantages. Among these is the limited water supply available from Floyds Fork. Floyds Fork has an average annual discharge of 163 cfs, with zero flow on a 7-day, 10-year low flow recurrence interval. The maximum water consumption for a 2,400-MWe plant would be 154 cfs, which would literally take up most of the river's flow. A smaller plant perhaps could be provided with sufficient cooling water, assuming adequate reservoir storage could be developed. However, topography does not favor a reservoir of large capacity. Reservoir and plant site development would require extensive relocation and/or protection of numerous residents, roads, pipelines, and communication lines.

French Creek Site

This site is located on the Ohio River flood plain in Meade County, Kentucky, approximately 5 miles downstream from Brandenburg, Kentucky, at River Mile 651. The site has approximately 600 acres of nearly level land. Adjacent upland areas could possibly be used for some portions of facility construction. Two ravines adjacent to the flood plains could be used for solid waste storage.

Chief advantages are avilability of Ohio River water and barge transportation, the opportunity for onsite solid waste disposal, sparsity of residences on the site and in the vicinity, and distance from existing industrial sources of air emissions.

Disadvantages are the small site size (site development would require diversion of French Creek in order to fully utilize level area available), lack of rail transportation, and distance of transmission (approximately 18 miles to Applicant's 345-kV line near Mill Creek across the Ohio River and through Indiana). Site elevations are quite low, with much of the site at roughly elevation 410 and Ohio River pool elevation at 383.

Harrods Creek Site

This site is located in Oldham County adjacent to the Jefferson County line. It is an upland area of approximately 400 acres of gently sloping land at the junction of Harrods Creek and South Fork. Its chief advantage is its proximity to the Louisville load center.

The chief disadvantages are its location in a rapidly urbanizing area, proximity to other sources of air emissions, small site size, and cost of developing a water supply from the Ohio River. Rail transportation would have to be developed from the Louisville and Nashville rail line near O'Bannon for a distance of approximately 6 miles. A reservoir could be constructed on the South Fork at Harrods Creek, but not without causing substantial adverse environmental effects and disruption to existing and future residential land use.

Paradise Bottom Site

This site is located in Meade County, Kentucky on the flood plain of the Ohio River (River Mile 659), approximately 12 miles downstream from Brandenburg, Kentucky. The nearly level portion of the site is roughly 0.5 mile wide and 2 miles long, or about 650 acres. Typically, the elevation of the site is between 420 and 440 feet; the adjacent river pool elevation is 383 feet. There are several small ponds on the site. Bluffs adjacent to the site rise precipitously to elevations of 700 to 800 feet.

The chief advantage of the site is its access to Ohio River water and barge transportation. The site vicinity is sparsely populated and there are no nearby industrial sources of air emissions. The area across the river in Indiana is in state forest.

The chief disadvantages are the limited site size and lack of solid waste disposal areas onsite, inaccessibility by highway and rail, and the 20-mile transmission distance across Indiana to the nearest point on the Applicant's 345-kV grid. Also, an Ohio River crossing would be required.

Skylight Site

This site is an upland area approximately 1 mile east of U.S. Highway 42, 1 mile south of Skylight, and about 2 miles from the Ohio River. There are 800 to 900 acres of relatively level land in this vicinity. The general elevation of the site is 750 feet, or about 330 feet above the Ohio River.

The chief advantages of the site are its upland location and associated good ventilation, which allow for use of shorter, less expensive stacks. Also, the topography and elevation would allow either mechanical or natural draft cooling towers. Another advantage is its proximity (less than 6 miles) to the Applicant's 345-kV transmission line and the Louisville load center.

Disadvantages of the site are: (1) the existing land use is devoted largely to horse ranches and stables and associated land improvements with high real estate values; (2) the area is under the urban thrust from Louisville; and (3) coal could not be delivered directly to the site by barge. Conveyance systems from the Ohio River, however, may be technically feasible, although expensive and with associated adverse environmental impacts. In the absence of such facilities, coal would have to be delivered by rail. The nearest existing rail line is the Louisville and Nashville at Buckner, approximately 5 miles to the southeast. Rough topography exists between the site and Buckner, and construction would be expensive, including a difficult crossing over Harrods Creek Valley.

Taylor Creek Site

This site is located in Oldham County, Kentucky on the Ohio River flood plain (River Mile 588). It is north of Harmony Village and approximately 15 miles from downtown Louisville.

The chief advantages of this site are access to Ohio River water and barge transportation, proximity to load center, favorable site elevation and drainage, and opportunity to use nearby ravines for solid waste storage.

The chief disadvantage is the fact that the area is rapidly becoming urbanized with several new, high-value houses on the site and scattered throughout the nearby area. Other disadvantages are the limited size (approximately 700 acres) and the proximity to existing industrial sources of air emissions.

TECHNICAL APPENDIX II

CONDITIONS APPLICABLE TO INTAKE STRUCTURE EVALUATION

Site Conditions

1. Plant design elevation, 475 feet (USC and GS datum)
2. Circulating water system makeup flow for normal operations will be 39,500 gpm. This is estimated to occur about 60 percent of the time. The maximum intake requirements will be 69,000 gpm

Ohio River

1. Flow rate--annual average flow is approximately 112,000 cfs; 7-day, 10-year low flow is approximately 14,200 cfs. Consumptive use of river water (with maximum intake and discharge at 69,000 and 40,900 gpm respectively) is 28,000 gpm (63 cfs or 0.5 percent of the 7-day, 10-year low flow)
2. Elevation at site--normal pool is 419 feet USC and GS datum; design high water level is 475 feet; design low water level is 417 feet; river bottom at center of channel is about 392 feet
3. Velocity--annual average velocity is approximately 2.3 feet per second; at design high water level it is approximately 7.5 feet per second. The velocity at the plant site is lower on the Kentucky side than on the Indiana side of the river
4. Water temperature--monthly averages vary from about 81°F to 41°F
5. River bottom materials--soft sand-silt mixtures and compacted medium sand with occasional sections of graded gravel and sand-gravel mixtures in water over 10 feet deep
6. Aquatic environment--species along the Kentucky shoreline in this area of the river are of low biological value

TA-7 and TA-8 are blank.

TECHNICAL APPENDIX III

DATA AND ASSUMPTIONS FOR SOLID WASTE DISPOSAL CALCULATIONS

Criteria

The following general concepts served as criteria in the study and evaluation of alternatives:

1. All systems, disposal sites, and methods must be environmentally acceptable
2. All plant solid wastes will be disposed of onsite or at near-site locations available for purchase and development by the Applicant
3. The waste disposal system ultimately used should not be a source of unit- or plant-forced outage
4. Water usage in the disposal methods should be kept to a minimum to prevent excessive wastewater treatment needs
5. The Applicant would have control over the entire process of waste disposal
6. Usage of prototype equipment and processes should be minimized
7. Need for unit material handling equipment--i.e., trucks, bulldozers, graders, etc.--should be minimized or eliminated
8. Storage capacities will be determined for a storage depth having a 4-foot freeboard
9. The bottom ash pond will be sized to accept the entire station's output of bottom ash for the life of the plant
10. Site soil conditions should be suitable for a stable foundation
11. Onsite pond diking shall be designed for flood protection

Data

1. Unit sizes and start-up dates:

   Unit 1 - 495 MWe - June 1983
   Unit 2 - 495 MWe - June 1985
   Unit 3 - 675 MWe - June 1987
   Unit 4 - 675 MWe - June 1989

2. Plant life: 30 years

TA-10, TA-11 and TA-12 are blank.

TECHNICAL APPENDIX III (Continued)

3. Capacity factor curve:

   1-20 years = 60 percent
   21-30 years = 25 percent

4. Maximum daily capacity factor: 80 percent

5. Net unit heat rate: 9,800 Btu/kWe

6. Coal analysis: Alston #1 Raw (see also Appendix F)

	Low	Typical	High
Btu	10,350	10,837	11,000

7. Scrubber reactant: Limestone ($CaCO_3$)

Assumptions

1. Design coal analysis:

	Low	Typical	High
a. Frequency (percent):	30	50	20

   b. Expected values:

Btu	10,723
Ash	16.3 percent
Sulfur	4.29 percent

2. Ash splits

   a. Bottom ash:

      1) If mixed with fly ash: 20 percent
      2) If stored separately: 30 percent

   b. Fly ash: 80 percent

3. Ash densities

   a. Bottom ash:

      1) For capacity calculations: 55 pcf (wet or dry)
      2) For structural: 110 pcf

b. Fly ash:

1)	For capacity purposes:	60 pcf (wet or dry)
2)	Silo storage:	70 pcf
3)	For structural:	90 pcf (dry or ponded)

4. Stoichiometric rate for wet scrubber with limestone reactant: 130 percent

5. Scrubber solid waste specific gravities and densities[a]:

   a. Specific gravity (density) of dry solids: 2.4 (150 pcf)

   b. Bulk specific gravity (density) of fly ash + bottom ash + scrubber sludge + chemical fixation agent mixture for capacity calculations: 1.2 (75 pcf)

6. Sludge dewatering characteristics:

	Expected Value Solids by Weight (percent)	Range Solids by Weight (percent)
a. From clarifier or thickener	20	15-65
b. From vacuum filter, pressure filter, or centrifuge	50	45-75

7. Calcium sulfite ($CaSO_3$) oxidation to calcium sulfate ($CaSO_4$) is 10 percent

8. Scrubber SO_2 removal efficiency is 90 percent

9. Ten percent by weight chemical fixation agent is added to the sludge and ash mixture

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[a] Valid for both predominately sulfite or sulfate sludges

TECHNICAL APPENDIX IV

Table 1

ESTIMATED QUANTITIES OF ASH AND SLUDGE PRODUCED BY A 495-MWe COAL-FIRED GENERATING STATION WITH A LIMESTONE FLUE GAS DESULFURIZATION SYSTEM

Type of Waste	Quantity Produced/Year (Short Tons)		Total Quantity Produced (Short Tons)	
	Years 1-20[a]	Years 21-30[b]	Years 1-20[a]	Years 21-30[b]
Fly ash, dry	15.5×10^4	6.46×10^4		
Bottom ash, dry	3.90×10^4	1.62×10^4		
Total ash, dry	19.4×10^4	8.08×10^4		
Total ash, wet (80% Solids)	24.3×10^4	10.1×10^4	486×10^4	587×10^4
Limestone sludge, dry				
$CaSO_3 \cdot 1/2\ H_2O$	16.8×10^4	7.00×10^4		
$CaSO_4 \cdot 2\ H_2O$	2.49×10^4	1.04×10^4		
$CaCO_3$, unreacted	6.45×10^4	2.69×10^4		
Total limestone sludge, dry	25.7×10^4	10.7×10^4	515×10^4	622×10^4
Limestone sludge, wet (50% Solids)	51.4×10^4	21.4×10^4	$1{,}028 \times 10^4$	$1{,}242 \times 10^4$
Total limestone sludge, wet (50% Solids) + ash, wet (80% Solids)	75.7×10^4	31.5×10^4	$1{,}514 \times 10^4$	$1{,}829 \times 10^4$

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[a] Average capacity factor = 60 percent.

[b] Average capacity factor = 25 percent.

TA-16, TA-17 and TA-18 are blank.

TECHNICAL APPENDIX IV (Continued)

Table 2

ESTIMATED QUANTITIES OF ASH AND SLUDGE PRODUCED BY A 675-MWe COAL-FIRED GENERATING STATION WITH A LIMESTONE FLUE GAS DESULFURIZATION SYSTEM

Type of Waste	Quantity Produced/Year (Short Tons)		Total Quantity Produced (Short Tons)	
	Years 1-20[a]	Years 21-30[b]	Years 1-20[a]	Years 21-30[b]
Fly ash, dry	21.1×10^4	8.8×10^4		
Bottom ash, dry	5.28×10^4	2.20×10^4		
Total ash, dry	26.4×10^4	11.0×10^4		
Total ash, wet (80% Solids)	33.0×10^4	13.8×10^4	660×10^4	798×10^4
Limestone sludge, dry				
$CaSO_3 \cdot 1/2\ H_2O$	23.0×10^4	9.56×10^4		
$CaSO_4 \cdot 2\ H_2O$	3.40×10^4	1.42×10^4		
$CaCO_3$, unreacted	8.80×10^4	3.67×10^4		
Total limestone sludge, dry	35.2×10^4	14.7×10^4	704×10^4	851×10^4
Limestone sludge, wet (50% Solids)	70.4×10^4	29.4×10^4	$1{,}408 \times 10^4$	$1{,}702 \times 10^4$
Total limestone sludge, wet (50% Solids) + ash, wet (80% Solids)	103×10^4	43.2×10^4	$2{,}068 \times 10^4$	$2{,}500 \times 10^4$

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[a] Average capacity factor = 60 percent.

[b] Average capacity factor = 25 percent.

TECHNICAL APPENDIX V

ACOUSTICAL DATA ACQUISITION AND REDUCTION INSTRUMENTATION

Description	Model	Serial No.
Bruel & Kjaer Precision Sound Level Meter	2203	451342
Bruel & Kjaer Octave Filter Set	1613	460876
Bruel & Kjaer 1" diameter Free Field Microphone with Random Incidence Corrector UA 0055 and Open Cell Foam Windscreen	4131	97947
Bruel & Kjaer Pistonphone Calibrator (250 Hz, 124 dB signal)	4220	
Bruel & Kjaer Precision Sound Level Meter	2203	196497
Bruel & Kjaer Octave Filter Set	1613	197971
Bruel & Kjaer 1" diameter Free Field Microphone with Random Incidence Corrector UA 0055 and Open Cell Foam Windscreen	4145	334993
Bruel & Kjaer Pistonphone Calibrator (250 Hz, 124 dB signal)	4220	
BBN Portable Monitoring System	704	6
Bruel & Kjaer 1" diameter Free Field Microphone with Random Incidence Corrector UA 0055 and Open Cell Foam Windscreen	4161	407518
Bruel & Kjaer Silica Adaptor	UA 0310	
General Radio Pre-amplifier	1560-P-42	348
BBN Portable Monitoring System	704	8
Bruel & Kjaer 1" diameter Free Field Microphone with Random Incidence Corrector UA 0055 and Open Cell Foam Windscreen	4161	407519
Bruel & Kjaer Silica Adaptor	UA 0310	

TA-21 and TA-22 are blank.

TECHNICAL APPENDIX V (Continued)

Description	Model	Serial No.
General Radio Pre-amplifier	156-P-42	1123
General Radio Acoustic Calibrator	1567	10098
Deuta-Werke Anemometer		263003
Bendix Psychometer	566	524072
Data Reduction Instrumentation		
Digital Equipment Corp. Computer	PDP-10	

TECHNICAL APPENDIX VI

MONTHLY RECORD OF FISHES COLLECTED FROM THE OHIO RIVER AND CORN AND BAREBONE CREEKS, JULY-OCTOBER 1975
TRIMBLE COUNTY GENERATING PLANT SITE

TECHNICAL APPENDIX VI

Table 1

NUMBERS OF FISH FROM CORN CREEK, BAREBONE CREEK, AND THE OHIO RIVER, JULY 9, 22, AND 23, 1975

Common Name	Scientific Name	Corn Creek	Barebone Creek	Ohio River
Longnose gar	*Lepisosteus osseus*			16
Skipjack herring	*Alosa chrysochloris*			3
Gizzard shad	*Dorosoma cepedianum*			5
Stoneroller	*Campostoma anomalum*	55	8	2
Carp	*Cyprinus carpio*			5
Silverjaw minnow	*Ericymba buccata*	28		
Emerald shiner	*Notropis atherinoides*	27		33
Common shiner	*Notropis cornutus*	236	25	
Rosefin shiner	*Notropis ardens*	12		
Bluntnose minnow	*Pimephales notatus*	12	2	1
Creek chub	*Semotilus atromaculatus*	46	3	
River carpsucker	*Carpiodes carpio*			1
White sucker	*Catostomus commersoni*	3		
Northern hog sucker	*Hypentelium nigricans*	2		
Smallmouth buffalo	*Ictiobus bubalus*			1
Spotted sucker	*Minytrema melanops*	1		
Golden redhorse	*Moxostoma erythrurum*	10		
Channel catfish	*Ictalurus punctatus*			1
White bass	*Morone chrysops*			6
Rock bass	*Ambloplites rupestris*			4
Green sunfish	*Lepomis cyanellus*			1
Warmouth	*Lepomis gulosus*	1		1
Bluegill	*Lepomis macrochirus*	2		72
Longear sunfish	*Lepomis megalotis*	4	2	1

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TECHNICAL APPENDIX VI - Table 1 - (Continued)

Common Name	Scientific Name		Corn Creek	Barebone Creek	Ohio River
Smallmouth bass	Micropterus dolomieui		12		9
Largemouth bass	Micropterus salmoides				3
White crappie	Pomoxis annularis		1		
Rainbow darter	Etheostoma caeruleum		17		
Fantail darter	Etheostoma flabellare		6		
Johnny darter	Etheostoma nigrum		6		
Freshwater drum	Aplodinotus grunniens				3
		TOTAL	481	40	168

Source: University of Louisville, 1975a

TECHNICAL APPENDIX VI

Table 2

NUMBERS OF FISH FROM CORN CREEK, BAREBONE CREEK, AND THE OHIO RIVER, AUGUST 11 AND 24, 1975

Common Name	Scientific Name		Corn Creek	Barebone Creek	Ohio River
Longnose gar	*Lepisosteus osseus*				6
American eel	*Anguilla rostrata*				1
Skipjack herring	*Alosa chrysochloris*				18
Goldeye	*Hiodon alosoides*				1
Stoneroller	*Campostoma anomalum*		16		
Carp	*Cyprinus carpio*				6
Silverjaw minnow	*Ericymba buccata*		11		
Emerald shiner	*Notropis atherinoides*				35
Common shiner	*Notropis cornutus*		56	65	
Rosefin shiner	*Notropis ardens*			42	
Bluntnose minnow	*Pimephales notatus*		179		
Creek chub	*Semotilus atromaculatus*		20	5	
Golden redhorse	*Moxostoma erythrurum*		1		1
Channel catfish	*Ictalurus punctatus*				1
White bass	*Morone chrysops*				1
Bluegill	*Lepomis macrochirus*				4
Smallmouth bass	*Micropterus dolomieui*				2
Spotted bass	*Micropterus punctulatus*				2
Largemouth bass	*Micropterus salmoides*				3
Rainbow darter	*Etheostoma caeruleum*		5		
Fantail darter	*Etheostoma flabellare*		2	1	
Johnny darter	*Etheostoma nigrum*		4		
Freshwater drum	*Aplodinotus grunniens*				1
		TOTAL	294	113	82

Source: University of Louisville, 1975a

TECHNICAL APPENDIX VI

Table 3

NUMBERS OF FISH FROM CORN CREEK, BAREBONE CREEK, AND THE OHIO RIVER, SEPTEMBER 3, 23, AND 24, 1975

Common Name	Scientific Name	Corn Creek	Barebone Creek	Ohio River
Longnose gar	Lepisosteus osseus			4
Gizzard shad	Dorosoma cepedianum			3
Stoneroller	Campostoma anomalum	2		
Carp	Cyprinus carpio			3
Silverjaw minnow	Ericymba buccata	1		
Emerald shiner	Notropis atherinoides	40		37
Common shiner	Notropis cornutus	91	44	
Rosefin shiner	Notropis ardens	1	29	
Bluntnose minnow	Pimephales notatus	5	4	
Creek chub	Semotilus atromaculatus		1	
White sucker	Catostomus commersoni	1		
Northern hog sucker	Hypentelium nigricans	1		
Golden redhorse	Moxostoma erythrurum			1
Channel catfish	Ictalurus punctatus			2
White bass	Morone chrysops			3
Warmouth	Lepomis gulosus	1		
Bluegill	Lepomis macrochirus	18		1
Smallmouth bass	Micropterus dolomieui	7		1
Largemouth bass	Micropterus salmoides			1
Fantail darter	Etheostoma flabellare	4		
Johnny darter	Etheostoma nigrum	1		
Sauger	Stizostedion canadense			2
Freshwater drum	Aplodinotus grunniens			1
	TOTAL	173	78	59

Source: University of Louisville, 1975a

TECHNICAL APPENDIX VI

Table 4

NUMBERS OF FISH FROM CORN CREEK, BAREBONE CREEK, AND THE OHIO RIVER, OCTOBER 9 AND 24, 1975

Common Name	Scientific Name	Corn Creek	Barebone Creek	Ohio River
Longnose gar	*Lepisosteus osseus*			1
Skipjack herring	*Alosa chrysochloris*	2		2
Gizzard shad	*Dorosoma cepedianum*	8	2	10
Goldeye	*Hiodon alosoides*			1
Stoneroller	*Campostoma anomalum*	7		
Carp	*Cyprinus carpio*			1
Popeye shiner	*Notropis ariommus*	15		
Emerald shiner	*Notropis atherinoides*	430		
Rosefin shiner	*Notropis ardens*	16	38	
Common shiner	*Notropis cornutus*	30	25	
Bluntnose minnow	*Pimephales notatus*	15	1	
Creek chub	*Semotilus atromaculatus*	2	6	
White bass	*Morone chrysops*			6
Green sunfish	*Lepomis cyanellus*		1	
Bluegill	*Lepomis macrochirus*	33	2	
Longear sunfish	*Lepomis megalotis*	1	1	
Smallmouth bass	*Micropterus dolomieui*	2		
White crappie	*Pomoxis annularis*	1		
Rainbow darter	*Etheostoma caeruleum*	8	1	
Fantail darter	*Etheostoma flabellare*	3	1	
Johnny darter	*Etheostoma nigrum*	1		
Logperch	*Percina caprodes*	1		
Sauger	*Stizostedion canadense*	—	—	31
	TOTAL	575	78	52

Source: University of Louisville, 1975b

TECHNICAL APPENDIX VII

LOUISVILLE GAS AND ELECTRIC COMPANY
TRIMBLE COUNTY GENERATING STATION - UNIT 1
PROJECT 31-7296-101

REPORT ON THE SEISMICITY OF THE TRIMBLE COUNTY SITE

January 3, 1977
Revised April 15, 1977

FLUOR PIONEER INC.
CHICAGO, ILLINOIS 60606

TA-32, TA-33 and TA-34 are blank.

TABLE OF CONTENTS

SECTION	TITLE	PAGE
1.0	Introduction	1
2.0	Additional Seismic Information	1
3.0	Conclusions	6
4.0	Reference	7
	Figures	8
	Table 1	21
	Appendix	23

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1.0 INTRODUCTION

The purpose of this report is to provide the results of a review of the most recent literature concerning the seismicity of the region containing the Trimble County Site and to arrive at a reasonable expected ground acceleration.

2.0 ADDITIONAL SEISMIC INFORMATION

The following points emerge from the studies of the seismicity of the Central United States region.

a. The Trimble County Site and its immediate vicinity is free of faults. This is seen in the Regional Tectonic Map-Faults, Figure 1, prepared for the Marble Hill Nuclear Generating Station (1).

b. There are no epicenters of major earthquakes in the site area. Epicenters of few small earthquakes (MM Intensity ≤ VI) are located within a 50 mile radius around the site, Figure 2. Reoccurrence of these earthquakes may produce small effects (MM intensity ≤ V) at the site. The site is located in the Illinois Basin Seismotectonic region which is strikingly devoid of major earthquake epicenters. This region separates the two fairly active tectonic regions, namely, the Reelfoot Seismogenic region and the Western Ohio Seismogenic region. This observation is important to the discussions presented later in this document.

c. Nuttli (2) has plotted the epicenters of all earthquakes with maximum MM intensity of VI or greater that have occurred in the Central United States since 1843 - a period of 134 years, Figure 3. There have been no major activity in the site area for a radius of more than 50 miles. Based on these observations and other studies (1) the proposed site region may be considered as having low seismic activity.

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d. The 1976 Uniform Building Code Seismic Zone Map of the United States, Figure 4, places the Trimble County Site in Zone 2, indicative of moderate damage and corresponding to MM intensity VII. This map is based on the maximum intensity ever felt at a location without taking into account the frequency of occurrence. It also combines the two relatively active seismic regions mentioned in b. above and ignores the stable Illinois Basin region. It is more appropriate to draw conclusions from the seismic risk analysis of the region than from a generalized map such as the one shown on Figure 4.

e. The seismic activity which the site has seen in the past and may see in the future is due to major earthquakes occurring at remote epicenters (greater than 250 miles) and due to smaller earthquakes at relatively closer epicenters. This activity is seen in the isoseismal, (3) for the December 16, 1811 New Madrid earthquake, Figure 5; the Anna, Ohio earthquake of March 9, 1937, Figure 6; and the Hamilton County, Illinois earthquake of November 9, 1968, Figure 7. Perhaps the greatest seismic activity experienced by the site in the recent past is due to the 1811-1812 New Madrid earthquakes. Nuttli's isoseismal map, Figure 5, places the site in MM intensity VII for this earthquake.

The attenuation of intensity with distance is seen to be drastically slower for the Central and Northeastern United States than it is for Northern California, Figure 8, Bolt (4). Bolt point out in the same reference that, "Generally speaking, intensity assessments on, say, the Modified Mercalli scale are doubly biased in the upward direction. First, the estimate of intensity at a particular place in a shaken area usually depend on the item of observation which is rated highest in the descriptive scale. In this way, report of land slides often cause a site to be rated VIII to IX on the Modified Mercalli scale, although it is known that land slides are easily triggered, even without earthquakes. The next step is usually to draw isoseismal contours separating areas of uniform intensity level This enveloping of the data again puts an upper bound on the intensity. Bias in measurement is also accompanied by bias in interpretation. Any study of the original felt reports and damages brings to light cases where overassessments of scale values are made. There seems to be a close correlation between the scarcity of earthquakes and high assessments.

One aspect of this is demonstrated in Figure 1 (Figure 8 of this report), where intensity curves show the attenuation with distance for the northwest, the central part and the west of the United States. It is clear that, although the western curve comes from the great 1906 earthquake, the intensities in the east run 1 to 2 scale units higher than those reported in the west. Of course, part of this gap may be real due to differences in earthquake mechanism and crustal properties. Nevertheless, it is advisable when evaluating a site to go back to the original descriptive material and re-evaluate it in the light of modern knowledge of effects of ground shaking on buildings of differend kinds."

From these recent studies, it is estimated that a reoccurrence of the New Madrid earthquakes may produce a MM intensity VI to VII shaking at the site. This estimate is on the "worst case" basis and does not account for the frequency of occurrence or the probability of exceedance (seismic risk). These concepts are discussed in the following.

f. Like other natural phenomena, such as, extreme winds and floods, the seismic event should also be approached from a probabilistic point of view. Studies for the seismic risk associated with a given region, Cornell and Merz (5), or with a given site (1, 6) are emerging. The basis of establishing a seismic level at a site in this approach is not the "worst case" event but rather a high confidence level that the earthquake level will not be exceeded in the life of the plant.

A risk analysis (2) of this type has been made for the Marble Hill site. Based on the available data on the frequency of occurrence and attentuation with distance, the Curve A of Figure 9 is established for the Marble Hill Site. Since the Trimble County site is in the same seismogenic region and close to the Marble Hill site, the result generated in Figure 9 should be applicable to the Trimble County site.

To establish the site intensity, the annual risk or the average return period should be established. Recent seismic risk maps (7) have based the intensity or acceleration levels on a return period of 500 years. This return period may also be viewed approximately as a 10 percent probability of exceeding the calculated site intensity for a 50 year life of the structure. For a 500 year return period, the site intensity lies between VI and VII. This intensity value agrees with the estimation given in e. above. The next step is to establish the ground acceleration value.

g. Nuttli (3) points out that the intensity - acceleration relationship for the Central United Earthquakes is very different from those obtained from Western United States earthquakes such as Gutenberg and Richter (8), Coulter, Waldron and Devine (9), and Trifunac and Brady (10). From Figure 9 and the note on Page 248 of Nuttli paper (3), which is reproduced as Figure 10 of this report, it is seen that for the same intensity, the accelerations produced by the Central United States earthquakes are about one-eighth of the corresponding accelerations produced by Western United States earthquakes. From Figure 10 of this report, it can be estimated that an MM intensity IV Central United States earthquake produces a maximum acceleration of 0.3 per cent of gravity and a MM intensity VII produces 0.7 percent of gravity. These numbers are very low and should not be directly used. However, the studies by Nuttli do indicate that the characteristics of the Central United States earthquakes are quite different from those of the Western United States.

h. The design earthquakes given by Nuttli (2), for the Central United States is reproduced in as Table 1 of this report.

The Trimble County site falls in Region 3e as shown in Figure 11. The site is roughly 250 miles from Region 1, 50 miles from Region 2 and is in Region 3 (5 miles). From Table 1, the accelerations corresponding to the 1 H_z waves are the controlling acceleration. It is seen that the maximum acceleration at the Trimble County Site from any of the three design earthquakes does not exceed 3 percent of gravity. This agrees with the acceleration obtained from the acceleration vs. MM intensity relationship (Nuttli curve) for the Marble Hill Site, given in Figure 12, for an intensity between IV and VII.

Using the more conservative result from g. and h., it is estimated that the Trimble County site design earthquake for a 500 year return period has an MM intensity between IV and VII with a corresponding ground acceleration of 3 percent of gravity.

i. There has been considerable activity in the scientific and research communities towards preparing seismic ground acceleration maps on a national basis. The Applied Technology Council based in California and funded by the National Science Foundation has prepared a draft standard for seismic design (ATC-3). In this standard, a seismic acceleration map is presented. This map was essentially reproduced in the December, 1976 Civil Engineering issue and is given as Figure 13 of this report. Also the United States Geological Survey has recently released an earthquake hazard map in which the contour lines represent the percent of gravity for the horizontal seismic acceleration. Both maps are based on an earthquake return period of 500 years. Both maps give the acceleration of ground shaking on a firm strata (solid rock on strata having shear wave velocity in excess of 3500 ft/sec). Surficial geology at soil sites should be accounted for to obtain surface motions. The USGS release is given as Appendix   to this report.

From the ATC-3 map, the Trimble County site is estimated to experience a ground shaking of less than 5 percent of gravity (around 3 percent) whereas from the USGS map, the site would see around 4 percent of gravity.

These values are in close agreement to the 3 percent value obtained from the investigation of the regional seismotectonics and thus provide an independent check.

3.0 CONCLUSIONS

A brief review of the seismic characteristics of Central United States, in general, and the Trimble County site, in particular, has been made. Results of a seismic risk study taking into account the local earthquakes and tectonic features compare favorably with latest seismic acceleration maps prepared for the conterminous United States.

The following conclusions are reached:

a. The Trimble County Site is considered to be in a region of low seismic activity.

b. The design earthquake on firm ground at the site, based on a 500 year return period, is estimated to have a Modified Mercalli intensity between VI and VII and a ground acceleration value of 3 percent of gravity.

4.0 REFERENCES

1. Preliminary Safety Analysis Report (PSAR) for the Marble Hill Nuclear Generating Station, Public Service of Indiana, Docket No. STN 50-546.

2. Nuttli, O.W., "State of the Art for Assessing Earthquake Hazards in the United States. Design Earthquakes for the Central United States", Report 1, Miscellaneous Paper 5-73-1, U. S. Army Engineer Waterways Experiment Station, Vicksburg, Miss., January, 1973.

3. Nuttli, O. W., "The Mississippi Valley Earthquakes of 1811 and 1812: Intensities, Ground Motion and Magnitudes", Bull. Seis. Soc. Am., Feb., 1973, pp 227-248.

4. Bolt, B. A., "Prediction of Strong Ground Motion for Site Evaluations", Lecture Notes, Recent Advances in Earthquake Resistant Design of Structures, University of California, Berkeley, California, June 21-25, 1976.

5. Cornell, C. A., and Merz, H. A., "Seismic Risk Analyses of Boston", Journal of Structural Division, A.S.C.E., October, 1975, pp. 2027-2043.

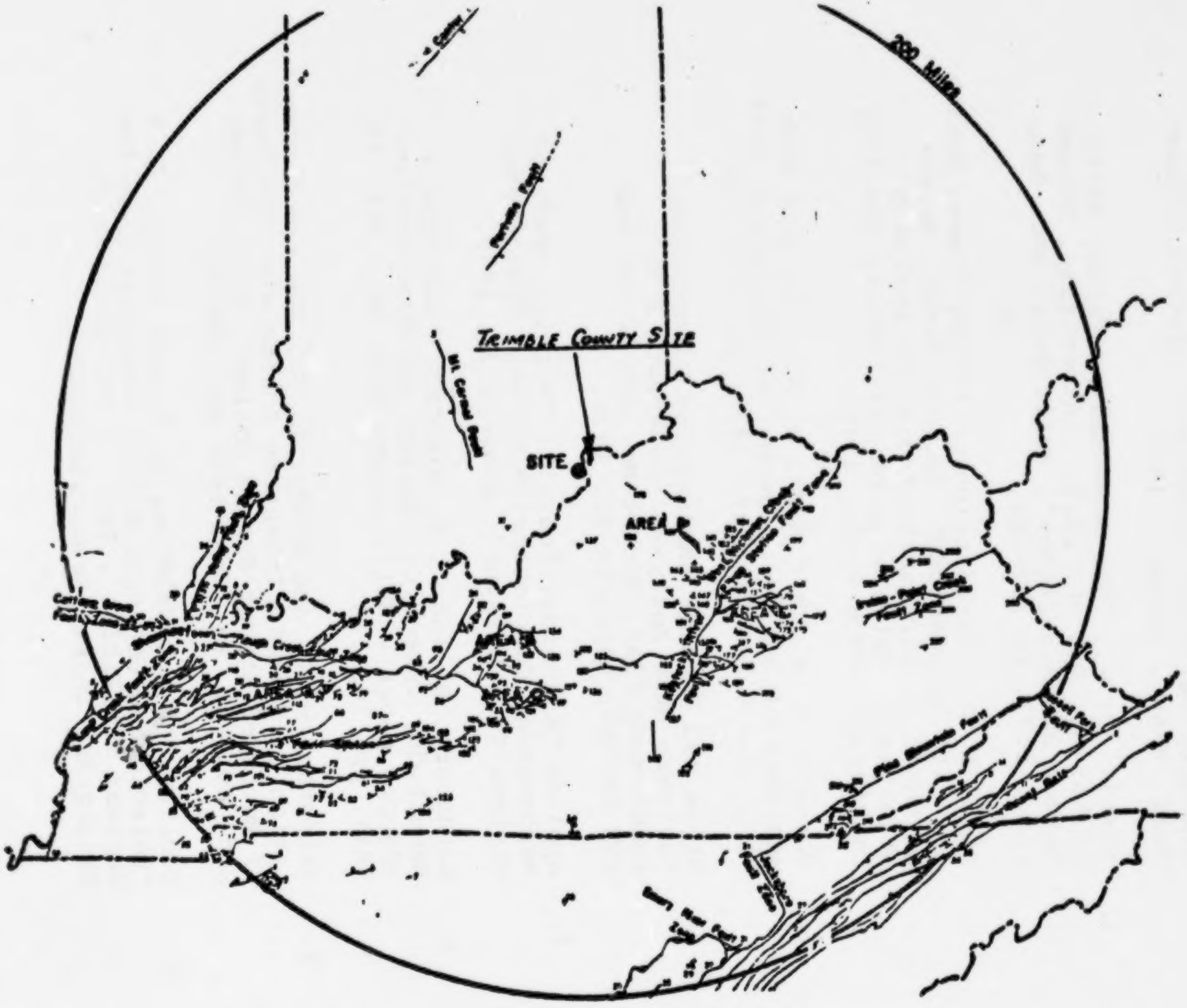
6. Stone and Webster Engineering Corporation, "Seismic Risk Analyses Koshkonong Site", Koshkonong PSAR, Docket No. STN 50-502 and STN 50-503, Appendix 2F, 1975.

7. Applied Technology Council, "Working Draft of Recommended Comprehensive Seismic Design Provisions for Building", January 31, 1976.

8. Gutenberg, B. and C. F. Richter, "Earthquake Magnitude, Intensity, Energy and Acceleration", (Second paper), Bull. Seism. Soc. Am., Vol. 46, 1956, pp. 105-143.

9. Trifunac, M. D. and Brady, A. G., "On the Correlation of Seismic Intensity Scales with the Peaks of Recorded Strong Ground Motion", Bull. Seism. Soc. Am. Vol. 65, Feb. 1975 pp. 139-162.

10. Coulter, H. W., Waldron, H. H. and Devine, J. F., "Seismic and Geologic Siting Considerations for Nuclear Facilities", Proc. Fifth World Conf. Earthquake Engr., Rome, Italy, 1973.



LEGEND

Fault, solid where positively or approximately located; dashed where inferred; queried where uncertain. Ball and bar on downthrown side; toothed on hanging wall of overthrust; arrows indicate relative horizontal displacement.

+ Faulted complex, astrobleme or cryptovolcanic.

• Fault identification number

NOTES

1. Only faults having traces two miles or longer are shown.
2. Faults are numbered according to state.
3. Data are summarized by states in Tables 2.5-4 through 2.5-11.
4. Unnamed fault areas are designated as Areas A, B, C, D and E. Both named fault zones and unnamed faulted areas are discussed in Section 2.5.1.1.5.1.1.2

25 0 25 50
Scale in Miles

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FIGURE 2.5-12

REGIONAL TECTONIC MAP - FAULTS
(GENERALIZED)

Figure 1

Reproduced from
best available copy.

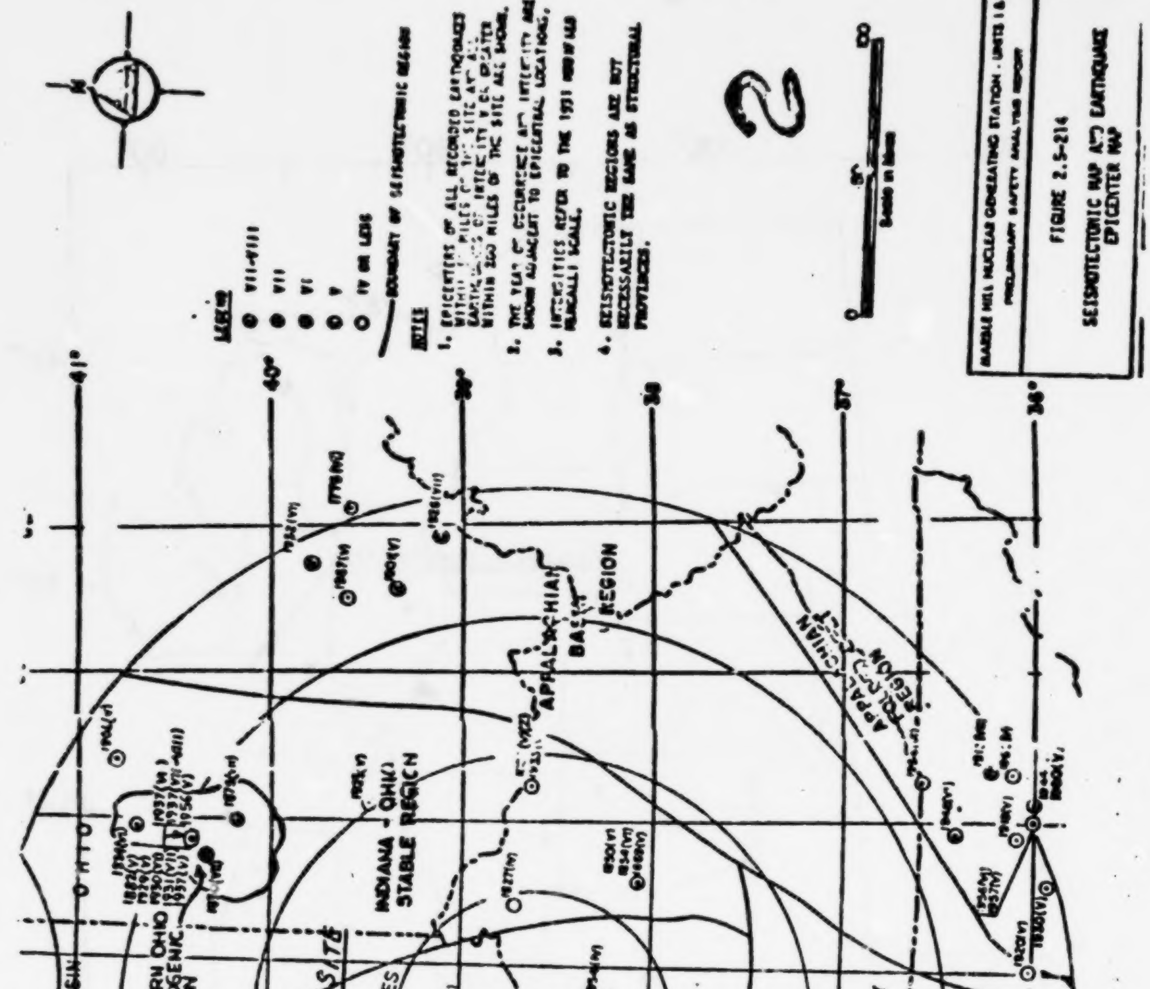
N
LEGEND
VII-VIII
VII
VI
V
IV OR LESS
BOUNDARY OF SEISMOTECTONIC REGION
NOTES
1. EPICENTERS OF ALL RECORDED EARTHQUAKES WITHIN 50 MILES OF THE SITE AND ALL EARTHQUAKES OF INTENSITY V OR GREATER WITHIN 200 MILES OF THE SITE ARE SHOWN.
2. THE YEAR OF OCCURRENCE AND INTENSITY ARE SHOWN ADJACENT TO EPICENTRAL LOCATIONS.
3. INTENSITIES REFER TO THE 1931 MODIFIED MERCALLI SCALE.
4. SEISMOTECTONIC REGIONS ARE NOT NECESSARILY THE SAME AS STRUCTURAL PROVINCES.
2
0
50
100
Scale in Miles
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FIGURE 2.5-214
SEISMOTECTONIC MAP AND EARTHQUAKE EPICENTER MAP
41°
40°
39°
38
37°
36°
ILLINOIS
INDIANA
OHIO
KENTUCKY
TENNESSEE
MICHIGAN BASIN REGION
WESTERN OHIO SEISMOGENIC REGION
INDIANA - OHIO STABLE REGION
APPALACHIAN BASIN REGION
APPALACHIAN FOLDED REGION
ILLINOIS BASIN REGION
WABASH - FAIRFIELD SEISMOGENIC REGION
WESTERN KENTUCKY FAULTED REGION
REELFOOT SEISMOGENIC REGION
TENNESSEE - KENTUCKY STABLE REGION
TRIMBLE COUNTY SITE
MARBLE HILL SITE
50 MILES
100 MILES
150 MILES

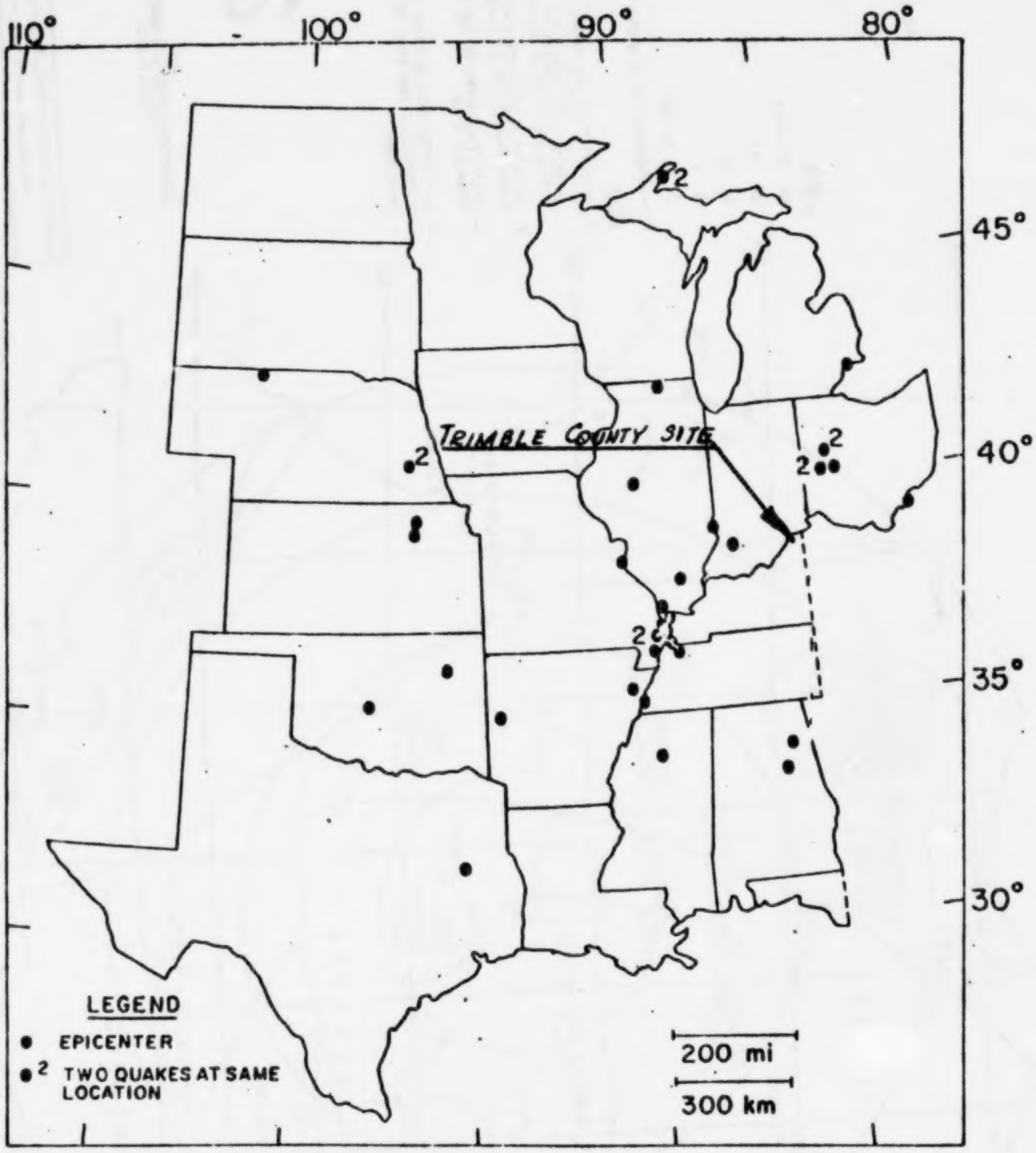

110°
100°
90°
80°
45°
40°
35°
30°
TRIMBLE COUNTY SITE
2
LEGEND
● EPICENTER
●2 TWO QUAKES AT SAME LOCATION
200 mi
300 km

Fig. 2. Plot of the epicenters of all earthquakes with MM_{max} intensity greater than VI that have occurred in the Central United States since 1843.

After Nuttli [2]

1976 EDITION 23-1

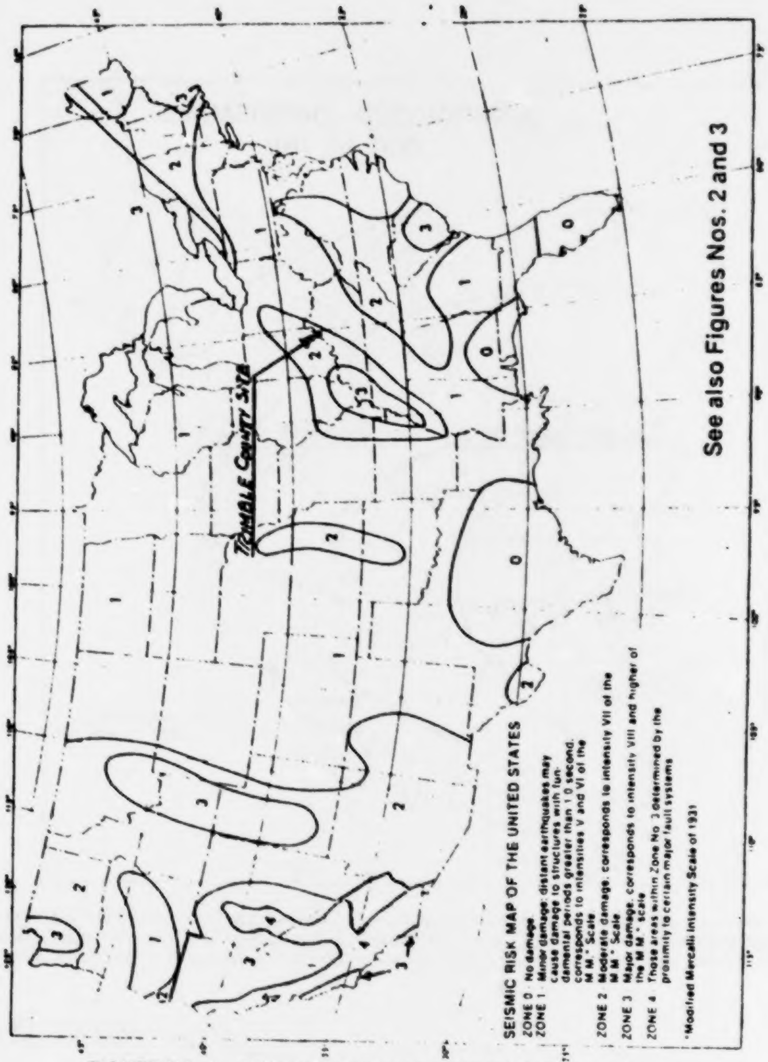

TRIMBLE COUNTY SITE
See also Figures Nos. 2 and 3
SEISMIC RISK MAP OF THE UNITED STATES
ZONE 0 · No damage
ZONE 1 · Minor damage: distant earthquakes may cause damage to structures with fundamental periods greater than 1.0 second; corresponds to intensities V and VI of the M.M.* Scale
ZONE 2 · Moderate damage; corresponds to intensity VII of the M.M.* Scale
ZONE 3 · Major damage; corresponds to intensity VIII and higher of the M.M.* scale
ZONE 4 · Those areas within Zone No. 3 determined by the proximity to certain major fault systems
*Modified Mercalli Intensity Scale of 1931
0
1
2
3
4

FIGURE NO. 1—SEISMIC ZONE MAP OF THE UNITED STATES

For areas outside of the United States see Appendix Chapter 23

149

After UBC 1976.

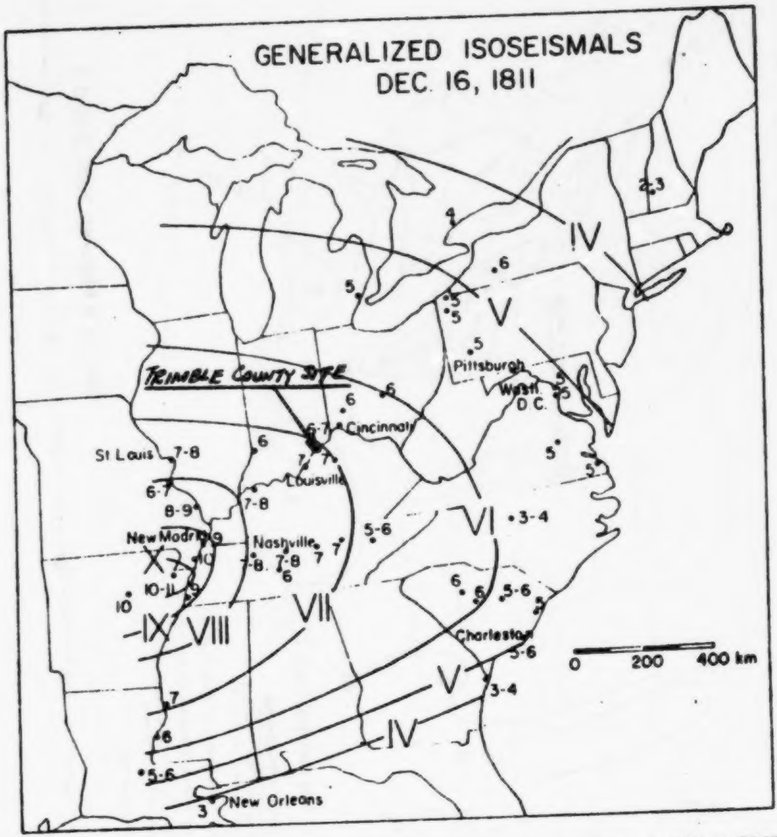
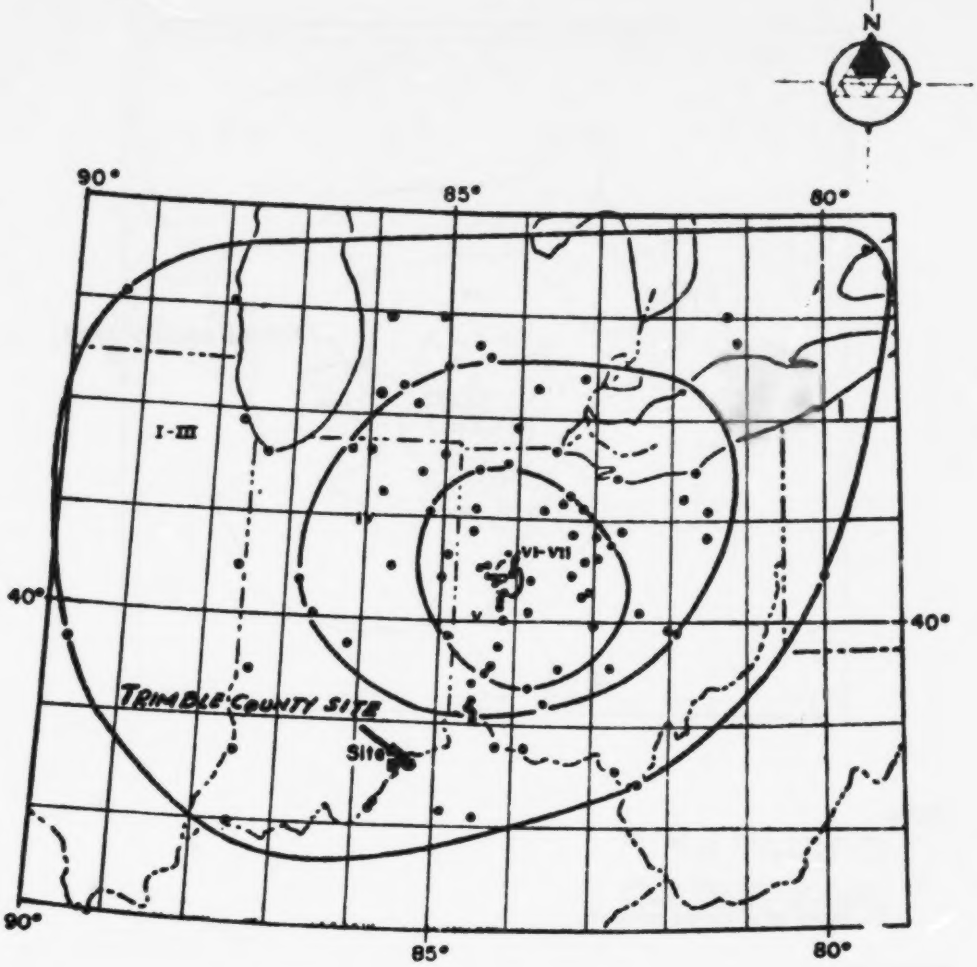

GENERALIZED ISOSEISMALS
DEC. 16, 1811
TRIMBLE COUNTY SITE
St Louis
New Madrid
Nashville
Louisville
Cincinnati
Pittsburgh
Wash. D.C.
Charleston
New Orleans
X
IX
VIII
VII
VI
V
IV
0
200
400 km

FIG. 1. Generalized isoseismal map of the earthquake of December 16, 1811 at 08^h15^m GMT. MM intensity values at individual points are given in Arabic numerals (see Table 1 for sources of information). The isoseisms, labeled with Roman numerals, indicate the outer bound of the region of specified intensity.

_After Nuttli [3]


N
90°
85°
80°
40°
40°
90°
85°
80°
I-III
IV
V
VI-VII
TRIMBLE COUNTY SITE
Site
MILES
50
0
50
100
150
200

NOTES:

1. INTENSITIES REFER TO THE 1931 MODIFIED MERCALLI SCALE.
2. ISOSEISMAL LINES INDICATE THE APPROXIMATE OUTER BOUNDARY OF THE REGION OF SPECIFIED INTENSITY.
3. THE DOTS INDICATE THE LOCATIONS AT WHICH INTENSITIES WERE OBSERVED.

REFERENCE:

DOCEKAL, JERRY; "EARTHQUAKES OF THE STABLE INTERIOR, WITH EMPHASIS ON THE MIDCONTINENT"; UNPUBLISHED PH.D. DISSERTATION, UNIVERSITY OF NEBRASKA, LINCOLN, NEBRASKA, 1971.

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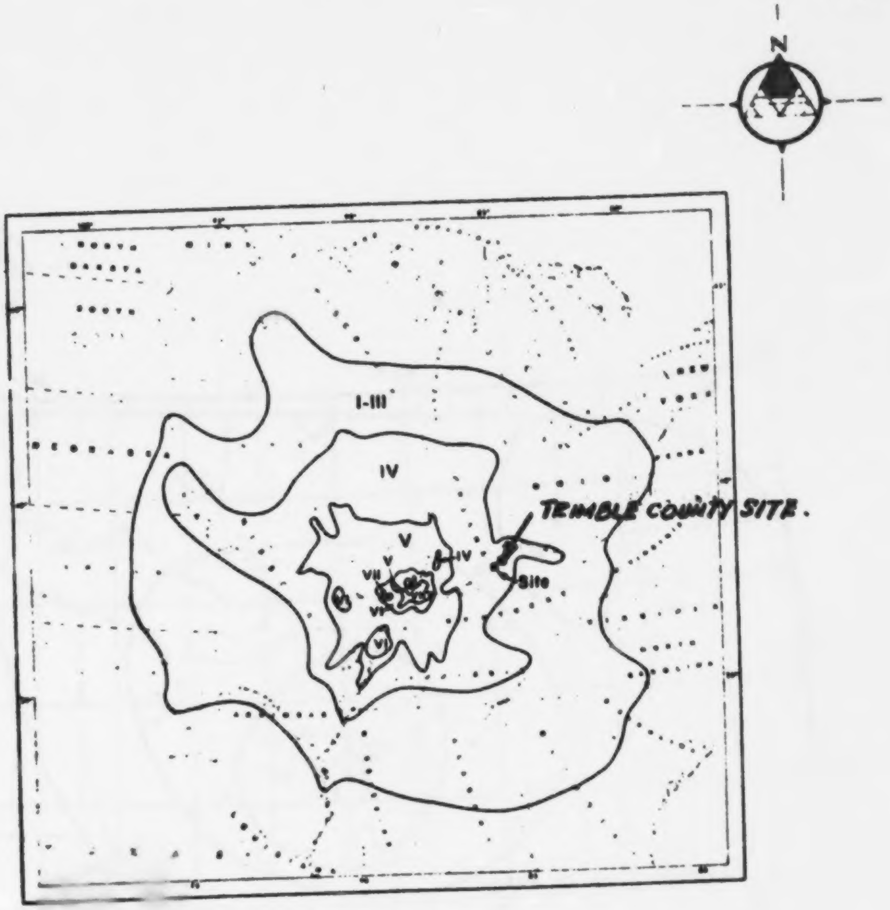
FIGURE 2.5-210

ISOSEISMIC MAP OF THE ANNA, OHIO
EARTHQUAKE OF MARCH 9, 1937



NOTES:

1. INTENSITIES REFER TO THE 1931 MODIFIED MERCALLI SCALE.

2. ISOSEISMAL LINES INDICATE THE APPROXIMATE OUTER BOUNDARY OF THE REGION OF SPECIFIED INTENSITY.

REFERENCE:

GORDON, D.W., BENNETT, T.J. HERRMAN, R.B., AND ROGERS, A.M., 1970, THE SOUTH-CENTPAL ILLINOIS EARTHQUAKE OF NOVEMBER 9, 1968: MACROSEISMIC STUDIES: SEISMOL. SOC. AMERICA BULL., VOL. 60, NO.3, p. 953-971.

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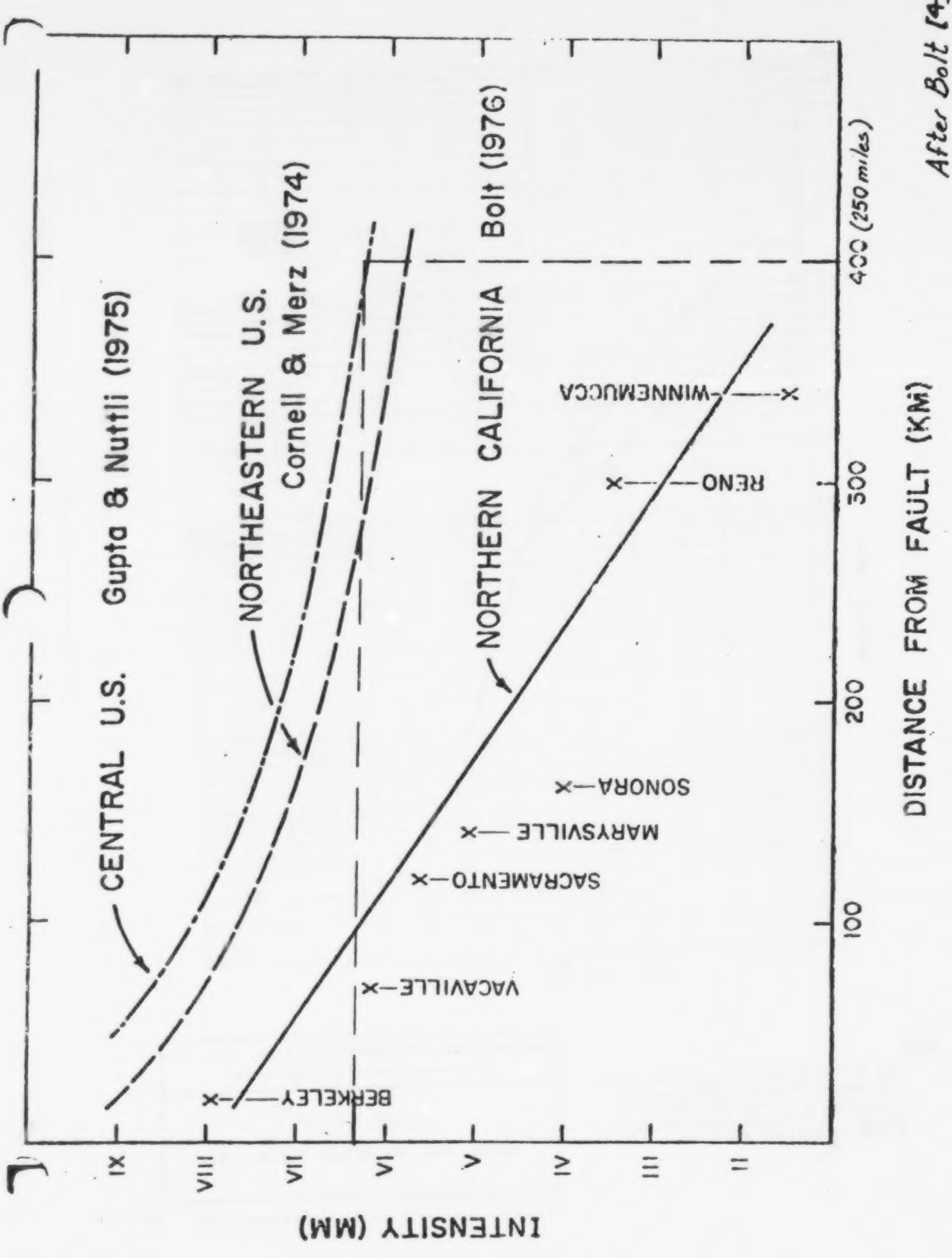
FIGURE 2.5-211

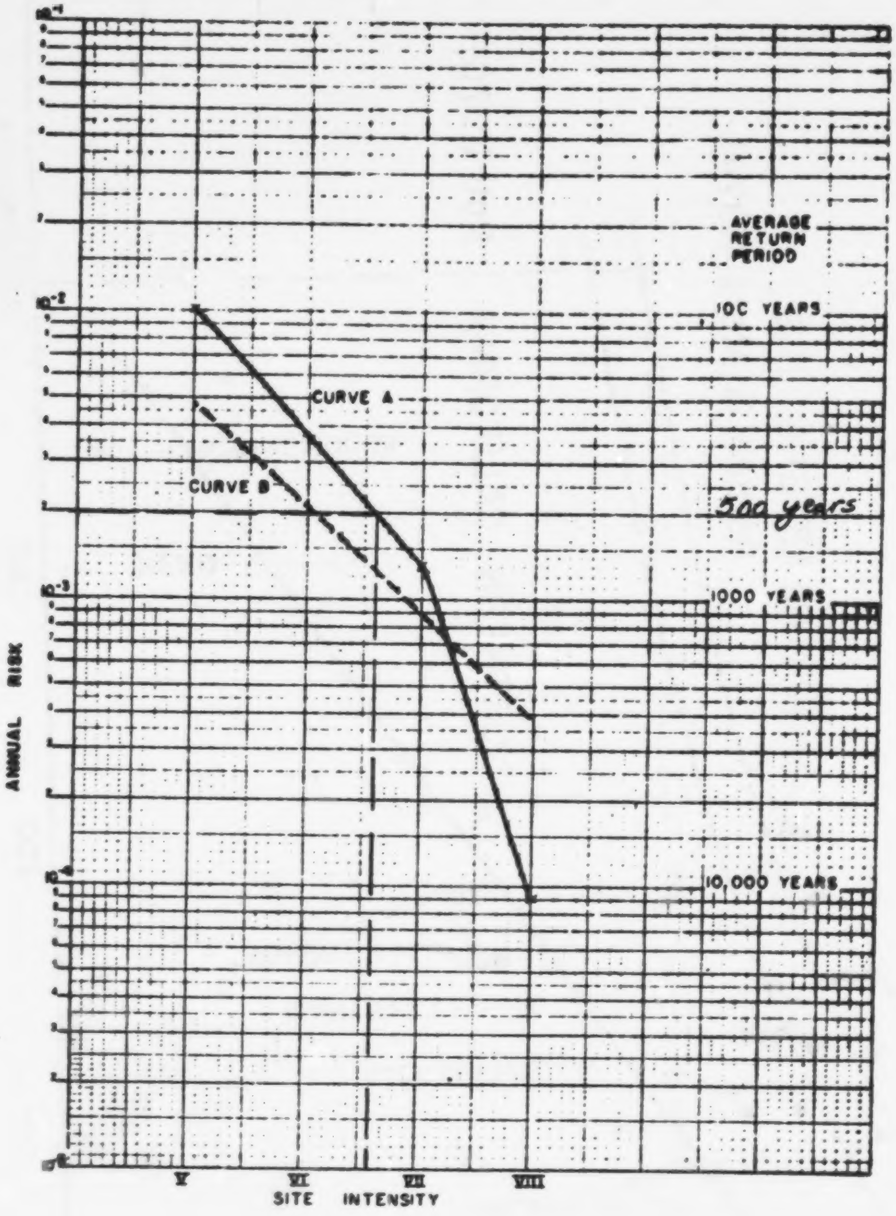
ISOSEISMIC MAP OF THE HAMILTON COUNTY, ILLINOIS EARTHQUAKE OF NOVEMBER 9, 1968



After Bolt [4]

TA-53

Figure 8



NOTE:

THE ORDINATE ON THE LEFT INDICATES THE ANNUAL RISK OF EQUALLING OR EXCEEDING A GIVEN SITE INTENSITY VALUE. A DETAILED DESCRIPTION IS GIVEN IN SECTION 2.5.2.11.1

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FIGURE 2.5-219

ANNUAL RISK AND RETURN PERIOD CURVE

Figure 9

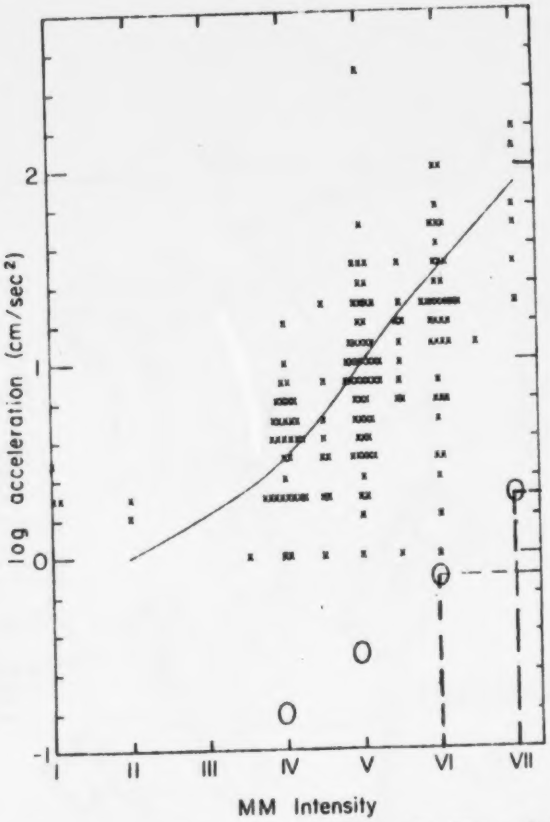


FIG. 9. Logarithm of particle acceleration versus MM intensity. The X's are data from California (Gutenberg and Richter, 1956, Table 5) and the O's are data of the November 9, 1968 Illinois earthquake. The curve is Gutenberg and Richter's (1956, Table 16) fit to the California data.

Page 248.

Note added in proof: In Figure 9, the actual value of the vertical component of acceleration for the 1968 Illinois earthquake was mistakenly plotted, rather than three times this quantity, as stated in the text. Thus, all the data points plotted as circles in Figure 9 should have their ordinates increased by 0.5 units.

The author is indebted to Mr. Warner Howe of Gardner and Howe, Memphis, Tennessee, for pointing out this error to him.

After Nuttli [3]

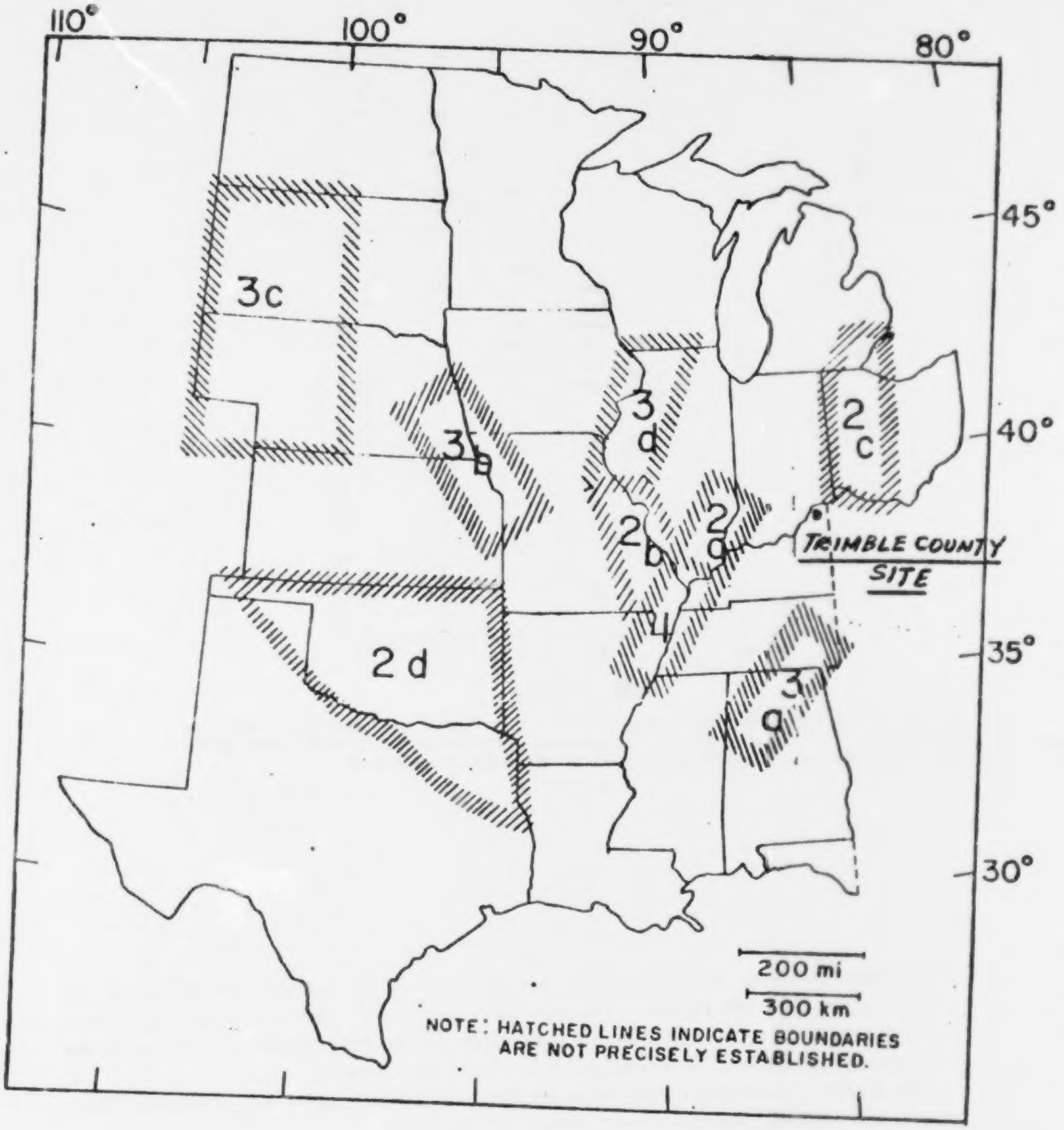
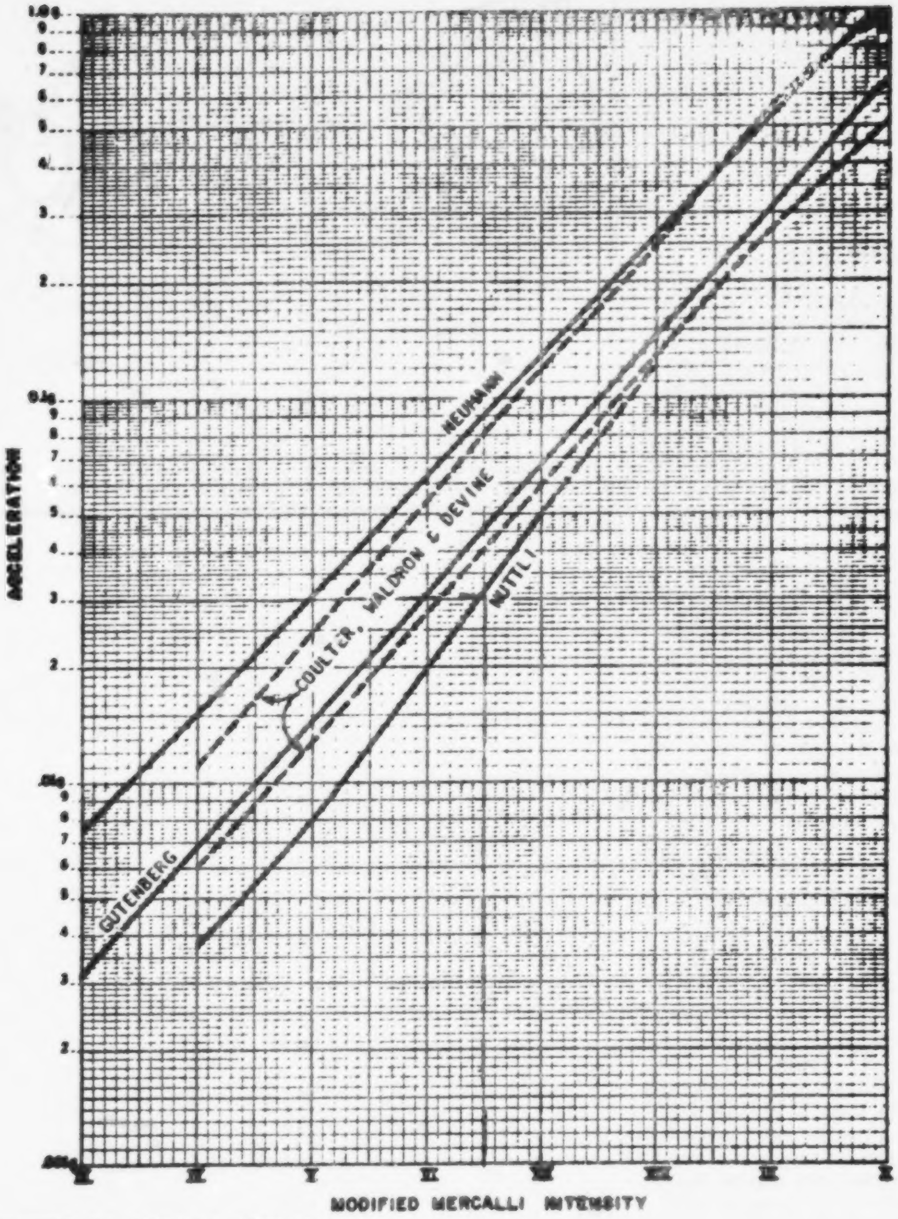

110°
100°
90°
80°
45°
40°
35°
30°
3c
3 b
3 d
2 c
2 b
2 a
1
2 d
3 a
TRIMBLE COUNTY SITE
200 mi
300 km
NOTE: HATCHED LINES INDICATE BOUNDARIES ARE NOT PRECISELY ESTABLISHED.

Fig. 5. Approximate boundaries of seismic regions 1, 2, and 3 in the Central United States. The design earthquake specified for seismic region 1 might be expected to occur anywhere within region 1. Similarly, the design earthquake specified for region 2 might be expected to occur anywhere in region 2a, 2b, 2c, or 2d. The design earthquake specified for region 3 can be expected to occur anywhere in region 3a, 3b, 3c, or 3d and less frequently in region 3e, which is taken to be all the area of the Central United States not enclosed by the hatched lines in the figure

After Nuttli [2]



REFERENCES: COULTER, H.W., WALDRON, H.H., AND DEVINE, J.F., 1973, SEISMIC AND DESIGN CONSIDERATIONS FOR NUCLEAR FACILITIES, PROCEEDINGS OF THE FIFTH WORLD CONFERENCE ON EARTHQUAKE ENGINEERING, ROME, ITALY, PAPER NO. 302.

GUTENBERG, BENO, AND RICHTER, C.F., 1942, EARTHQUAKE MAGNITUDE, INTENSITY, ENERGY, AND ACCELERATION: SEISMOL. SOC. AMERICA BULL., VOL. 32, PP. 163-191.

NEUMANN, F., 1954, EARTHQUAKE INTENSITY AND RELATED GROUND MOTION: UNIVERSITY OF WASHINGTON PRESS, SEATTLE.

NUTTLI, O.W.- SEE TEXT FOR EXPLANATION

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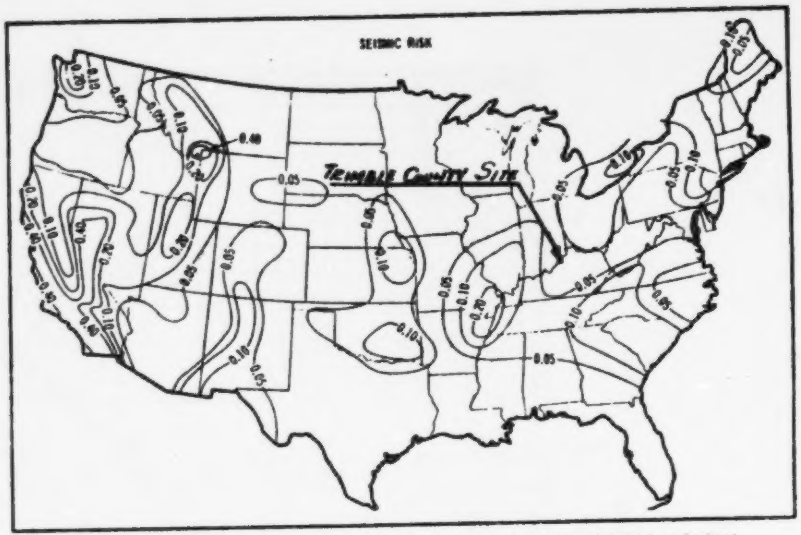
FIGURE 2.5-215

EARTHQUAKE ACCELERATION V. MM INTENSITY

Figure 12



Seismic risk map. Its predecessor map gave earthquake-acceleration contours based on highest accelerlion ever recorded. New map modifies those contours to take into account frequency of occurrence.

Seismic risk map

California's Applied Technology Council has prepared the accompanying map, "Effective Peak Acceleration".

Note that highest effective peak acceleration contour is 0.4 G. In the 1971 San Fernando, Calif. earthquake, for example, considerably higher accelerations were recorded. But the areas where such high G's are deemed possible are so small that they could not be shown on the map.

Also, most structures are founded on soil. High acceleration peaks tend to be damped by the soil; the Algermissen map, which was the standard until now, showed accelerations in rock. (The oppo[illegible] is true with the lower peak acceleratio[illegible] overlying soil increases these. Thus this new map shows higher effective G levels in low-G areas.)

Another innovation in the new map: it takes into account frequency of occurrance of earthquakes. The Algermissen map did not. The chance that accelerations shown will not be exceeded during a 50-year period is estimated at 90%.

Some cautions about inflexibly applying the map in building codes and regulations: "Considering the significant cost of designing a structure for extreme ground motions, it is undesirable to require such a design unless there is high probability that the extreme motion will occur, or unless there is a particularly severe penalty associated with failure or nonfunctioning of the structure. (Thus a nuclear power plant or a hospital might be so designed, but a furniture warehouse, perhaps not. Ed.)

"Second, a building properly designed for a particular ground motion will provide considerable protection to the lives of occupants during a more severe motion.

"Third, even if it were desirable to design for the extreme ground motion, it is impossible, at this time, to get agreement among experts as to the largest credible (acceleration). This is especially true for the less seismic portions of the country." (preprint 2805, "Development of Expectancy Maps and Rist Analysis," by Neville Donovan, Dames & Moore, San Francisco; Bruce Bolt, University of California; and Robert Whitman, MIT)

Figure 13

TABLE I

Table 3

Design Earthquake for Regions 1, 2, and 3*

Distance miles	0.3-Hz Waves Displacement cm	Particle Velocity cm/sec	Acceleration g	1-Hz Waves Displacement cm	Particle Velocity cm/sec	Acceleration g	3-Hz Waves Displacement cm	Particle Velocity cm/sec	Acceleration g
				Region 1					
5	120-260	260-540	0.56-1.1	12-21	78-140	0.48-0.88	1.2-2.4	26-52	0.54-1.1
10	120	260	0.56	12	78	0.48	1.2	26	0.54
15	80	170	0.35	8.2	54	0.34	0.80	17	0.35
20	60	130	0.26	6.3	42	0.26	0.60	12	0.26
25	48	100	0.21	5.2	35	0.22	0.47	9.8	0.21
35	34	72	0.15	3.9	26	0.16	0.39	6.7	0.14
50	24	50	0.10	2.8	19	0.12	0.21	4.4	0.095
75	15	32	0.066	2.0	13	0.083	0.12	2.5	0.055
100	11	23	0.047	1.6	10	0.065	0.072	1.7	0.037
150	6.5	14	0.029	1.1	6.8	0.044	0.043	0.85	0.019
200	4.6	9.8	0.020	0.80	5.2	0.033	0.026	0.53	0.012
300	2.7	5.7	0.012	0.52	3.4	0.021	0.012	0.24	0.005
				Region 2					
5	12-26	26-54	0.056-0.11	1.2-2.1	7.8-14	0.048-0.088	0.12-0.24	2.6-5.2	0.054-0.11
10	12	26	0.056	1.2	7.8	0.048	0.12	2.6	0.054
15	8.0	17	0.035	0.82	5.4	0.034	0.080	1.7	0.035
20	6.0	13	0.026	0.63	4.2	0.026	0.060	1.2	0.026
25	4.8	10	0.021	0.52	3.5	0.022	0.047	0.98	0.021
35	3.4	7.2	0.015	0.39	2.6	0.016	0.039	0.67	0.014
50	2.4	5.0	0.010	0.28	1.9	0.012	0.021	0.44	0.0095
75	1.5	3.2	0.0066	0.20	1.3	0.0083	0.012	0.25	0.0055
100	1.1	2.3	0.0047	0.16	1.0	0.0065	0.0072	0.17	0.0037
150	0.65	1.4	0.0029	0.11	0.68	0.0044	0.0043	0.085	0.0019
200	0.46	0.98	0.0020	0.080	0.52	0.0033	0.0026	0.053	0.0012
300	0.27	0.57	0.0012	0.052	0.34	0.0021	0.0012	0.024	0.0005
				Region 3					
5	4.0-8.6	8.6-18	0.019-0.037	0.40-0.70	2.6-4.7	0.016-0.029	0.040-0.080	0.86-1.7	0.018-0.037
10	4.0	8.6	0.019	0.40	2.6	0.016	0.040	0.86	0.018
15	2.7	5.7	0.012	0.27	1.8	0.011	0.027	0.57	0.012
20	2.0	4.3	0.0087	0.21	1.4	0.0087	0.020	0.40	0.0087
25	1.6	3.3	0.0070	0.17	1.2	0.0073	0.016	0.33	0.0070
35	1.1	2.4	0.0050	0.13	0.87	0.0053	0.013	0.22	0.0047
50	0.80	1.7	0.0033	0.093	0.63	0.0040	0.0070	0.15	0.0032
75	0.50	1.1	0.0022	0.067	0.43	0.0026	0.0040	0.083	0.0018
100	0.37	0.77	0.0016	0.053	0.33	0.0022	0.0024	0.057	0.0012
150	0.22	0.47	0.00097	0.037	0.23	0.0015	0.0014	0.028	0.00063
200	0.15	0.33	0.00067	0.027	0.17	0.0011	0.00087	0.018	0.00040
300	0.090	0.19	0.00040	0.017	0.11	0.0007	0.00040	0.008	0.00017

---

* The hard-rock ground motions (displacement, particle velocity, and acceleration) are the vector resultants of the vertical and horizontal components of the sustained maximum surface wave motion. At distances of 75 miles, the duration of this motion will be as much as 30 sec. At distances of 100 miles and greater, the duration can be as much as 1 to 2 min, generally increasing with increasing epicentral distance.

After Nuttli [2]

DEPARTMENT of the INTERIOR
news release

GEOLOGICAL SURVEY Forrester (703) 860-7444

For release: July 19, 1976

QUAKE HAZARD MAP OF U.S. PREPARED

A new report and map for the conterminous (48) United States appraising the potential ground shaking produced by earthquakes have been prepared by the U.S. Geological Survey, Department of the Interior.

The map represents a first attempt to show expectable levels of earthquake shaking hazards on a national basis.

Levels of ground shaking for different regions of the U.S. are shown on the map by contour lines which express in percentages of the force of gravity the maximum amount of horizontal acceleration (shaking) likely to occur at least once in a 50-year period. For example, a contour at 60 percent of gravity means that scientists are 90 percent certain that the region in the vicinity of the contour will not experience ground shaking more than 60 percent of the force of gravity.

Contours at 4, 10, 20, 40, and 60 percent of gravity are shown on the map, which is published at a scale of 1:7,500,000 (1 inch equals 120 miles). All contours are expressed at the 90 percent probability level.

The acceleration map provides a quick method for evaluating the relative earthquake hazard throughout the United States. For example, during a 50-year period, accelerations of 10 percent of gravity may be expected at least once in portions of New England, while many areas of California can expect to experience accelerations of 60 percent of gravity at least once during the same period.

The areas of greatest hazard from earthquake shaking in the conterminous 48 States are shown to include parts of California, Nevada, Washington, Montana, Wyoming, Utah, Idaho, New Mexico, Arizona, Missouri, Arkansas, Tennessee, Kentucky, and Illinois. The States with least hazard are Florida, Louisiana, Wisconsin, Minnesota, and North Dakota.

(more)

Request copies from Dr. S. T. Algermissen, U S G S
Stop 978, 25046 Denver Federal Center, Denver CO 80225

In the western half of the Nation, the 60 percent of gravity contour encloses parts of the San Andreas fault zone in southern and western California, and an area extending from southeast California northward into central Nevada. In the mid-continent area, the highest acceleration is the 19 percent of gravity for the region of the Mississippi Valley that includes extreme southern Illinois, southeast Missouri, extreme western Kentucky and Tennessee, and the northeast corner of Arkansas. Farther eastward, the maximum acceleration is 11 percent of gravity, which occurs in South Carolina and in central parts of Vermont and New Hampshire.

Accelerations on the map are those estimated to occur on solid rock. Because the surface materials in many areas of the United States are not solid rock, the maximum acceleration at a particular location may be quite different from that shown on the map. For example, depending upon surface geologic materials, the acceleration may be two to three times larger, or in a few cases even slightly lower than the values shown on the map.

The report and map will be useful in the earthquake-resistant design of structures because the horizontal force on a building during an earthquake is proportional to the horizontal ground acceleration.

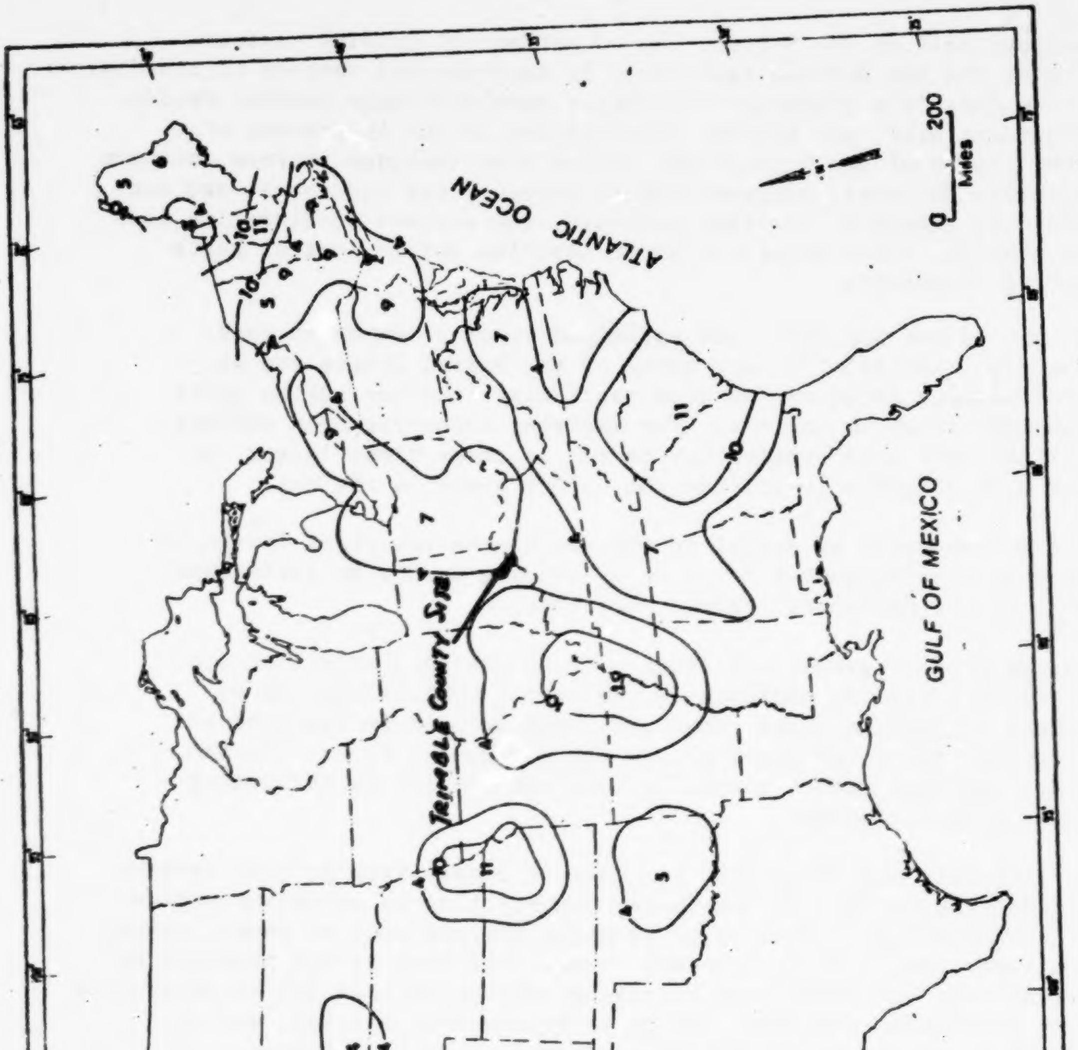
In earthquake-prone regions, buildings must be designed to resist substantial horizontal forces in addition to the normal vertical forces of gravity. While buildings in quake-prone areas are adequately designed to accommodate vertical forces of gravity, and for horizontal forces exerted by strong winds, the same cannot always be said with regard to horizontal shaking produced by earthquakes.

The USGS scientists emphasize that exposure to damage from seismic shaking is steadily increasing because of continuing urbanization in earthquake-prone regions and the increasing complexity of lifeline systems such as power, water, transportation, and communication systems. Thus, data such as are provided by the new report and map are helpful in assessing earthquake hazards, in developing methods such as earthquake-resistant design to reduce such hazards, and in insurance studies as an aid in estimating potential earthquake losses.

Copies of the preliminary report and map, "A Probabilistic Estimate of Maximum Acceleration in Rock in the Contiguous United States," by S. T. Algermissen and D. M. Perkins, and printed as USGS Open-File Report No. 76-416, are available for public inspection at the following USGS libraries: Room 4C100, National Center, 12201 Sunrise Valley Dr., Reston, Va.; 345 Middlefield Road, Menlo Park, Calif.; and the Federal Center, Denver, Colo. In addition, copies are available for public review at the following USGS Public Inquiries Offices: 108 Skyline Bldg., 508 Second Ave., Anchorage, Alaska; 7638 Federal Building, 300 N. Los Angeles St., Los Angeles, Calif.; 504 Custom House, 555 Battery St., San Francisco, Calif.; 1012 Federal Bldg., 1961 Stout St., Denver, Colo.; 1028 General Services Bldg., 19th & F Sts., N.W., Washington, D.C.; 1C45 Federal Bldg., 1100 Commerce St., Dallas, Texas; 8015 Federal Bldg., 125 S. State St., Salt Lake City, Utah; 1C402 National Center, Reston, Va.; and 678 U.S. Court House, West 920 Riverside Ave., Spokane, Wash.

# # # #

(See attached map.)


ATLANTIC OCEAN
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PACIFIC OCEAN
TRIMBLE COUNTY SITE
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Map shows expectable levels of earthquake shaking hazards. Levels of ground shaking for different regions are shown by contour lines which express in percentages of the force of gravity the maximum amount of shaking likely to occur at least once in a 50-year period.

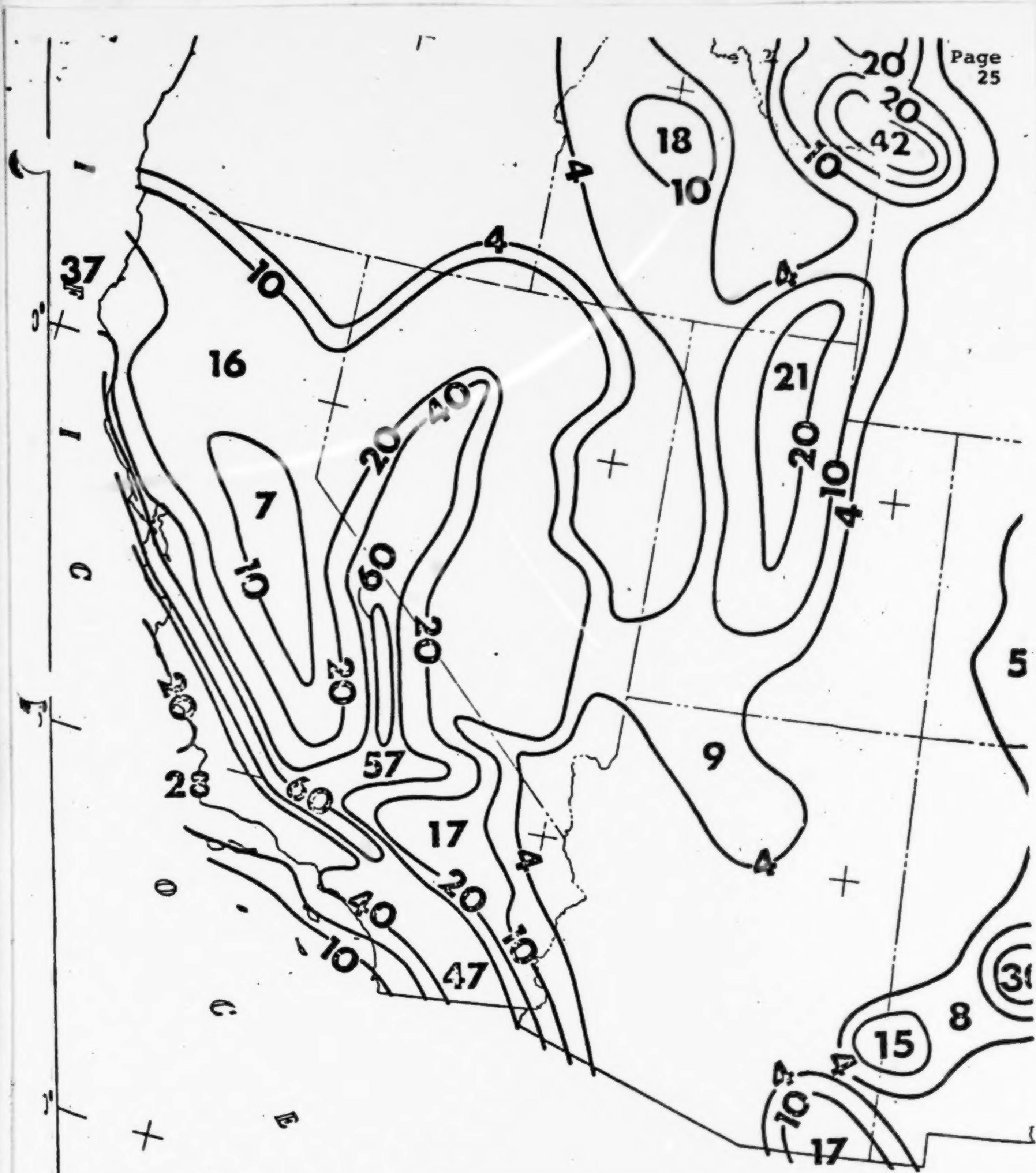
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Figure 4

Preliminary Map of
Horizontal Acceleration (Expressed As Percent Of
Gravity) In Rock With 90 Percent Probability
Of Not Being Exceeded In 50 Year

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TECHNICAL APPENDIX VIII

NUMBERICAL DISPERSION MODEL STUDY OF TRIMBLE COUNTY COOLING TOWER PLUMES

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NUMERICAL DISPERSION MODEL STUDY
OF
TRIMBLE COUNTY COOLING TOWER PLUMES
LOUISVILLE GAS & ELECTRIC COMPANY

Prepared for
FLUOR PIONEER INC.
under contract

By
ESSCO
Environmental Science and Services Corp.
New York, N. Y.

TR 102 February 1976

This report contains proprietary data; use or disclosure of such data is subject to contract provisions and to specific arrangements with ESSCO.

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TABLE OF CONTENTS

Section | Page

ABSTRACT . . . .

LIST OF TABLES . . . .

LIST OF FIGURES . . . .

I. INTRODUCTION 1

II. ESSCO COOLING TOWER PLUME IMPACT MODEL (COTPIM) 3

III. DISCUSSION OF RESULTS 4

- A. Plume Visibility 4
- B. Ground Level Fog and Ice 5
- C. Drift Deposition 7

IV. SUMMARY 8

REFERENCES 10

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LIST OF TABLES

Table Page

1. Cooling Tower Characteristics 11

2. Typical Ambient Conditions as Functions of Altitude, 270.4°k, 40% Relative Humidity, Low Velocity 12

3. Typical Ambient Conditions as Functions of Altitude, 270.4°k, 95% Relative Humidity, Low Velocity 13

4. Typical Ambient Conditions as Functions of Altitude, 294.3°k, 95% Relative Humidity, Low Velocity 14

5. Typical Ambient Conditions as Functions of Altitude, 270.4°k, 40% Relative Humidity, High Velocity 15

6. Weather Data Summary, Standiford Airport, Louisville, Kentucky, 1951-1961 16

7. Joint Frequency Distributions, Temperature-Velocity-Humidity, Standiford Field, Louisville, Kentucky, 1951-1961 17

8. Velocity-Direction Frequency Distribution, All Stabilities, Standiford Field, Louisville, Kentucky 18

9. Velocity-Direction Frequency Distributions, A & B Stabilities, Standiford Field, Louisville, Kentucky 19

10. Velocity-Direction Frequency Distributions, C & D Stabilities, Standiford, Field, Louisville, Kentucky 20

11. Velocity-Direction Frequency Distribution, E Stability, Standiford Field, Louisville, Kentucky 21

12. Drift Droplet Size Distribution 22

Table Page

13. Plume Characteristics, T = -15°C, Relative Humidity = 85%, V = 0.89 m/sec 23

14. Plume Characteristics, T = 10°C, Relative Humidity = 85%, V = 4.25 m/sec 24

15. Plume Characteristics, T = -2.78°C, Relative Humidity = 75%, V = 8.94 m/sec 25

16. Plume Characteristics, T = 10°C, Relative Humidity = 85%, V = 12.07 m/sec 27

17. Visible Plume Length 28

18. Annual Occurrence of Condensed Water Plumes . . 29

19. Average Frequencies of Visible Plume 30

20. Annual Occurrence of Tower Induced Ground Level Fog 31

21. Fogging Length 32

22. Average Frequencies of Fogging 33

23. Icing Length 34

24. Average Frequencies of Icing 35

25. Distributions of Drift Deposition, N & NNE Wind Directions 36

26. Distributions of Drift Deposition, NE & ENE Wind Directions 37

27. Distributions of Drift Deposition, E & ESE Wind Directions 38

28. Distributions of Drift Deposition, SE & SSE Wind Directions 39

29. Distributions of Drift Deposition, S & SSW Wind Directions 40

30. Distributions of Drift Deposition, SW & WSW Wind Directions 41

Table Page

31. Distributions of Drift Deposition, W & WNW Wind Directions 42

32. Distributions of Drift Deposition, NW & NNW Wind Directions 43

LIST OF FIGURES

Figure		Page
1.	Sketch of Plume Indicating Computational Scheme for Calculating Center Line Trajectory	44
2.	Sketch of Plume Under Ground Level Fogging Conditions	45
3.	Sketch of Plume Indicating Computational Scheme for Calculating Particle Deposition	46
4.	Visible Plume Characteristics, T = -15°C, Relative Humidity = 85%, W = 0.89 m/sec . . .	47
5.	Visible Plume Characteristics, T = 10°C, Relative Humidity = 85%, W = 4.25 m/sec . . .	48
6.	Visible Plume Characteristics, T = -2.78°C, Relative Humidity = 75%, W = 8.94 m/sec . . .	49
7.	Visible Plume Length as a Function of Relative Humidity	50
8.	Visible Plume Length as a Function of Atmospheric Temperature	51
9.	Visible Plume Length as a Function of Wind Velocity	52
10.	Annual Average Isopleths of Visible Plume Length	53
11.	Distributions of Drift Deposition as a Function of Droplet Diameter, Stability A, W = 0.89 m/sec	54
12.	Distributions of Drift Deposition for Stabilities A, C & E, W = 0.89 m/sec	55
13.	Distributions of Drift Deposition for Stabilities A, C & E, W = 4.25 m/sec	56
14.	Annual Average Isopleths of Drift Deposition .	57

ABSTRACT

A numerical modeling study utilizing the ESSCO Cooling Tower Plume Impact Model (COTPIM) has been carried out to assess the atmospheric effects associated with the cooling tower operations at the proposed Trimble County Plant. A finite difference technique was used to solve the governing conservation equations pertaining to the dynamic and thermodynamic properties of buoyant moist plumes to determine: plume trajectories, plume visibility characteristics, ground level fogging and icing potential due to tower plumes, and ground deposition of tower drift. Weather summary data (1951-1961) and star format data (1964) for Standiford Field, Louisville, Kentucky was used.

The results of the analysis indicate that:

1. Visible condensed water plumes occur to distances of 1, 2, 3, and 4 km with an annual frequency of 17.1, 13.7, 10.0 and 0.6%; respectively;
2. Ground level fogging occurs less than 30.5 hours per year;
3. Ground level icing occurs less than one hour per year;
4. Maximum ground level drift deposition is 432 kg/km^2/month and occurs at 100 m north of the plant.

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I. INTRODUCTION

The cooling system for the proposed Trimble County electric generating station will employ two hyperbolic natural draft cooling towers. The cooling towers will be used as a means of dissipating the power plant waste heat into the atmosphere instead of into the waters of the adjacent Ohio River. The waste heat, carried by the recirculating cooling tower water, will be absorbed by the ambient air drawn into the tower as the water cascades through the tower. The prime heat transfer mechanism in the tower will be evaporation of the cooling water. The characteristics of these two towers are listed in Table 1.

In order to evaluate the impact of the Trimble County cooling tower operations on the atmospheric environment, it is necessary to model the complex physical processes associated with the heat and moisture released into the atmosphere in the form of buoyant moist plumes.

The numerical modeling study described in this report utilizes the ESSCO Cooling Tower Plume Impact Model (COTPIM) to assess the atmospheric effects associated with the cooling tower operations at the proposed Trimble County plant. The objectives of the study were to determine:

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(a) the centerline trajectory and radius of the moist buoyant plumes as a function of downwind distance for each meteorological condition of interest;

(b) the length of visible plume and an estimate of the annual average frequency of plume visibility by calculating the local condensate mixing ratio in the plume as a function of applicable meteorological conditions;

(c) the potential for ground level fog formation and estimates of the annual average frequencies of ground level fog enhancement due to cooling tower operations;

(d) the potential for ground level icing and estimates of the annual average frequencies of ground level icing due to cooling tower operations;

(e) the ground deposition of tower drift, as a function of droplet size class, wind direction, wind velocity and atmospheric stability and the total annual average deposition for each wind direction.

The ESSCO COTPIM model and study results are discussed in the following sections.

II. ESSCO COOLING TOWER PLUME IMPACT MODEL (COTPIM)

The model description is proprietary and has been deleted from this study. A copy of the model description is on file in the EPA Region IV office in Atlanta.

III. DISCUSSION OF RESULTS

A. Plume Visibility

The results of the plume rise and visibility model consist of tables with the values of the vertical (z) and horizontal (x) coordinates of the plume axis, the vertical and horizontal velocity components, the mixing ratio, the radius of the plume, the temperature, the water mixing ratio and the density. The values of these quantities are given at each step along the axis up to the visibility limit or up to the point at which w = 0 . Typical results are presented in Tables 13-16.

The dependence of the maximum visible length on each of the parameters (temperature, wind velocity, humidity) is shown in Table 17. Typical plume trajectories and plume growth patterns are presented in Figures 4-6.

Figures 7-9 show the maximum visible length as a function of ambient parameters.

Table 18 lists the number of hours per year, and the percentage of time, that the Trimble County cooling tower plumes will be visible to a given distance. The data represents the total number of hours summed over the sixteen wind directions considered in the analysis.

It can be seen that plume visibility beyond a distance of 4 km occurs with an annual frequency of 50 hours or 0.6% of the time.

Table 19 lists the length of visible plume as a function of annual hours for the 16 compass directions. Frequencies of visible plumes are greatest for S, W, N and NW winds. For each of the above wind directions, visible plumes extend to distances of 1-3.4 km, 100 hours per year.

The data presented in Table 19 has been plotted in Figure 10 to show the extent of visible plumes in specified directions using percent frequencies of wind direction and speed, as well as temperature and wind speed-relative humidity occurrences for meteorological measurements obtained at Standiford Field, Louisville, Kentucky, 1951-1961. See Table 6.

B. Ground Level Fog and Ice

Cooling tower plumes have the potential to induce fog at ground level due to the large burden of moisture introduced into the ambient air. For natural draft cooling towers, this potential is minimized because of buoyancy effects and the great height of the towers. The maximum impact of natural draft cooling tower plumes on the ambient air occurs well above ground level. Only under special circumstances of plume downwash or plume trapping by inversions aloft will there be any potential for ground level fog formation.

The effects of tower-induced plume downwash have been included in this analysis in an approximate way. Inversion trapping effects were not considered here, but it is expected that buoyancy effects of the Trimble County plumes will be sufficient to allow the plumes to penetrate most low level inversions.

Table 20 lists the number of hours per year, and the percentage of time, that the Trimble County cooling tower plumes will present a potential for ground level fog formation.

It can be seen that fogging potential is confined mainly to the plant property. Fogging at 500 meters downwind of the plant will occur with an annual frequency of 19 hours.

Ground level fog at distances beyond 2,000 meters has a probability of occurrence less than one hour per year.

Tables 21-22 present the fogging length data and the predicted annual frequency of ground level fogging attributable to cooling tower operation.

The results show that the downwash cases (wind velocity larger than 12 m/sec) are the only cases responsible for fogging at ground level. Downwash conditions occur for N, NNE, S, WSW, WNW wind directions.

Tables 23-24 present the icing length data and the predicted annual frequency of ground level icing attributable to the cooling tower operation.

Icing appears in few cases with a very low frequency (less than 1 hour/year) giving rise to all zeros in Table 24.

C. Drift Deposition

The ground level drift distributions $\Lambda(p,x,u,s)$ for the 10 size particle classes are presented in Figure 11 for stability class A and wind velocity .89 m/sec.

In Figures 12-13 the total deposition is presented for two wind velocity and stability conditions.

The total deposition, due to all the size classes, is obtained by connecting the maxima of all the size particle diagrams to account for the discrete choice of the classes.

The total mean annual drift deposition for the 16 wind directions considered is presented in Tables 25-32 and in the isopleth diagrams shown in Figure 14. Table 29 shows that the maximum drift deposition of 432 kg/km^2/ month occurs for wind direction South at 100 m from the tower.

IV. SUMMARY

Based on the numerical model study performed utilizing the ESSCO COTPIM Model and Standiford Airport, Kentucky meteorological data (1951-1961), the following observations apply:

1) Visibility effect beyond 4 km from the plant are infrequent, occurring with an annual frequency of less than 50 hours or 0.6% of the time.

2) For S, W, N and NW winds, plumes are visible overhead for 100 hours per year at distances between 1 and 3.4 km.

3) Ground level fog due to cooling tower emissions is confined to plant property.

4) At 500 meters downwind of the plant ground level fog will occur with an annual frequency of 19 hours.

5) Ground level fog at distances beyond 2,000 meters has a less than one hour annual probability.

6) Ground level icing due to tower plume occurs with an annual frequency of less than one hour.

7) Maximum drift deposition corresponds to South winds.

8) Maximum drift deposition is 432 $kg/km^2/month$.

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COOLING TOWER DATA

Units	Height (ft)	Exit Diameter (ft)	Air (ACFM)	Exit Temp. (^{o}F)	Drift (gpm)	Exit Velocity (ft/min)
1 & 2	400	200	25.5×10^6	112^oF saturated	37	813
3 & 4	500	220	34.5×10^6	112^oF saturated	50	857

TABLE 1

Cooling Tower Characteristics

EXTERNAL CONDITIONS

HEIGHT M.	TEMPERATURE DEG.K	PRESSURE ATM.	DENSITY KG/M**3	MIXING RATIO KG/KG	HUMIDITY %	WIND VELOCITY M/SEC
0.	270.4	1.000	1.30	.12-02	40.	.0
50.	270.1	.994	1.30	.12-02	39.	1.3
100.	269.7	.987	1.29	.11-02	38.	1.6
150.	269.4	.981	1.29	.11-02	37.	1.8
200.	269.1	.975	1.28	.10-02	36.	1.9
250.	268.8	.969	1.27	.10-02	35.	2.0
300.	268.4	.963	1.27	.96-03	35.	2.1
350.	268.1	.957	1.26	.92-03	34.	2.2
400.	267.8	.951	1.25	.88-03	33.	2.2
450.	267.5	.945	1.25	.85-03	32.	2.3
500.	267.1	.939	1.24	.81-03	31.	2.4
550.	266.8	.933	1.23	.78-03	31.	2.4
600.	266.5	.927	1.23	.74-03	30.	2.5
650.	266.2	.922	1.22	.71-03	29.	2.5
700.	265.8	.916	1.22	.68-03	28.	2.5
750.	265.5	.910	1.21	.65-03	28.	2.6
800.	265.2	.905	1.20	.62-03	27.	2.7
850.	264.9	.899	1.20	.60-03	26.	2.7
900.	264.5	.894	1.19	.57-03	26.	2.8
950.	264.2	.888	1.19	.55-03	25.	2.8
1000.	263.9	.883	1.18	.52-03	24.	2.8
1050.	263.6	.877	1.17	.50-03	24.	2.9
1100.	263.2	.872	1.17	.48-03	23.	2.9
1150.	262.9	.866	1.16	.46-03	23.	2.9
1200.	262.6	.861	1.16	.44-03	22.	3.0
1250.	262.3	.856	1.15	.42-03	22.	3.0
1300.	261.9	.851	1.15	.40-03	21.	3.0
1350.	261.6	.845	1.14	.38-03	20.	3.0
1400.	261.3	.840	1.14	.36-03	20.	3.1
1450.	261.0	.835	1.13	.35-03	19.	3.1
1500.	260.6	.830	1.12	.33-03	19.	3.1
1550.	260.3	.825	1.12	.32-03	18.	3.2
1600.	260.0	.820	1.11	.30-03	18.	3.2
1650.	259.7	.815	1.11	.29-03	17.	3.2
1700.	259.3	.810	1.10	.28-03	17.	3.2
1750.	259.0	.805	1.10	.26-03	17.	3.3
1800.	258.7	.800	1.09	.25-03	16.	3.3
1850.	258.4	.795	1.09	.24-03	16.	3.3
1900.	258.0	.791	1.08	.23-03	15.	3.3
1950.	257.7	.786	1.08	.22-03	15.	3.3
2000.	257.4	.781	1.07	.21-03	15.	3.4

TABLE 2

Typical Ambient Conditions as Functions of Altitude, 270.4°k, 40% Relative Humidity, Low Velocity

EXTERNAL CONDITIONS

HEIGHT M.	TEMPERATURE DEG.K	PRESSURE ATM.	DENSITY KG/M**3	MIXING RATIO KG/KG	HUMIDITY %	WIND VELOCITY M/SEC
0.	270.4	1.000	1.30	.30-02	95.	.0
50.	270.1	.994	1.30	.28-02	93.	1.3
100.	269.7	.987	1.29	.27-02	91.	1.6
150.	269.4	.981	1.28	.26-02	88.	1.8
200.	269.1	.975	1.28	.25-02	86.	1.9
250.	268.8	.969	1.27	.24-02	84.	2.0
300.	268.4	.963	1.26	.23-02	82.	2.1
350.	268.1	.957	1.26	.22-02	80.	2.2
400.	267.8	.951	1.25	.21-02	78.	2.2
450.	267.5	.945	1.25	.20-02	76.	2.3
500.	267.1	.939	1.24	.19-02	74.	2.4
550.	266.8	.933	1.23	.18-02	73.	2.4
600.	266.5	.928	1.23	.18-02	71.	2.5
650.	266.2	.922	1.22	.17-02	69.	2.5
700.	265.8	.916	1.22	.16-02	67.	2.6
750.	265.5	.910	1.21	.15-02	66.	2.6
800.	265.2	.905	1.20	.15-02	64.	2.7
850.	264.9	.899	1.20	.14-02	63.	2.7
900.	264.5	.894	1.19	.14-02	61.	2.8
950.	264.2	.888	1.19	.13-02	59.	2.8
1000.	263.9	.883	1.18	.12-02	58.	2.8
1050.	263.6	.877	1.17	.12-02	57.	2.9
1100.	263.2	.872	1.17	.11-02	55.	2.9
1150.	262.9	.867	1.16	.11-02	54.	2.9
1200.	262.6	.861	1.16	.10-02	52.	3.0
1250.	262.3	.856	1.15	.99-03	51.	3.0
1300.	261.9	.851	1.15	.95-03	50.	3.0
1350.	261.6	.846	1.14	.90-03	49.	3.0
1400.	261.3	.840	1.13	.86-03	47.	3.1
1450.	261.0	.835	1.13	.83-03	46.	3.1
1500.	260.6	.830	1.12	.79-03	45.	3.1
1550.	260.3	.825	1.12	.75-03	44.	3.2
1600.	260.0	.820	1.11	.72-03	43.	3.2
1650.	259.7	.815	1.11	.69-03	42.	3.2
1700.	259.3	.810	1.10	.66-03	40.	3.2
1750.	259.0	.805	1.10	.63-03	39.	3.3
1800.	258.7	.800	1.09	.60-03	38.	3.3
1850.	258.4	.796	1.09	.57-03	37.	3.3
1900.	258.0	.791	1.08	.54-03	36.	3.3
1950.	257.7	.786	1.08	.52-03	35.	3.3
2000.	257.4	.781	1.07	.49-03	35.	3.4

TABLE 3
Typical Ambient Conditions as Functions of Altitude, 270.4°k, 95% Relative Humidity, Low Velocity

EXTERNAL CONDITIONS

HEIGHT M.	TEMPERATURE DEG.K	PRESSURE ATM.	DENSITY KG/M**3	MIXING RATIO KG/KG	HUMIDITY %	WIND VELOCITY M/SEC
0.	294.3	1.000	1.19	.15-01	95.	.0
50.	293.9	.994	1.18	.15-01	93.	1.3
100.	293.6	.989	1.18	.14-01	91.	1.6
150.	293.3	.983	1.17	.14-01	89.	1.8
200.	293.0	.977	1.17	.13-01	88.	1.9
250.	292.6	.972	1.16	.13-01	86.	2.0
300.	292.3	.966	1.16	.12-01	84.	2.1
350.	292.0	.961	1.15	.12-01	82.	2.2
400.	291.7	.955	1.15	.11-01	81.	2.2
450.	291.3	.950	1.14	.11-01	79.	2.3
500.	291.0	.944	1.14	.11-01	77.	2.4
550.	290.7	.939	1.13	.10-01	76.	2.4
600.	290.4	.933	1.13	.98-02	74.	2.5
650.	290.0	.928	1.12	.95-02	73.	2.5
700.	289.7	.923	1.12	.91-02	71.	2.6
750.	289.4	.918	1.11	.88-02	70.	2.6
800.	289.1	.912	1.11	.85-02	68.	2.7
850.	288.7	.907	1.10	.82-02	67.	2.7
900.	288.4	.902	1.10	.79-02	65.	2.8
950.	288.1	.897	1.09	.76-02	64.	2.8
1000.	287.8	.892	1.09	.73-02	63.	2.8
1050.	287.4	.887	1.08	.71-02	61.	2.9
1100.	287.1	.882	1.08	.68-02	60.	2.9
1150.	286.8	.877	1.08	.66-02	59.	2.9
1200.	286.5	.872	1.07	.63-02	58.	3.0
1250.	286.1	.867	1.07	.61-02	56.	3.0
1300.	285.8	.862	1.06	.59-02	55.	3.0
1350.	285.5	.857	1.06	.56-02	54.	3.0
1400.	285.2	.853	1.05	.54-02	53.	3.1
1450.	284.8	.848	1.05	.52-02	52.	3.1
1500.	284.5	.843	1.04	.50-02	51.	3.1
1550.	284.2	.838	1.04	.49-02	49.	3.2
1600.	283.9	.834	1.03	.47-02	48.	3.2
1650.	283.5	.829	1.03	.45-02	47.	3.2
1700.	283.2	.824	1.02	.43-02	46.	3.2
1750.	282.9	.820	1.02	.42-02	45.	3.3
1800.	292.6	.815	1.02	.40-02	44.	3.3
1850.	282.2	.811	1.01	.39-02	43.	3.3
1900.	281.9	.806	1.01	.37-02	42.	3.3
1950.	281.6	.802	1.00	.36-02	42.	3.3
2000.	281.3	.797	1.00	.34-02	41.	3.4

TABLE 4

Typical Ambient Conditions as Functions of Altitude, 294.3°k, 95% Relative Humidity, Low Velocity

EXTERNAL CONDITIONS

HEIGHT M.	TEMPERATURE DEG.K	PRESSURE ATM.	DENSITY KG/M**3	MIXING RATIO KG/KG	HUMIDITY %	WIND VELOCITY M/SEC
0.	270.4	1.000	1.30	.12-02	40.	.0
50.	270.1	.994	1.30	.12-02	39.	13.4
100.	269.7	.987	1.29	.11-02	38.	15.9
150.	269.4	.981	1.29	.11-02	37.	17.6
200.	269.1	.975	1.28	.10-02	36.	18.9
250.	268.8	.969	1.27	.10-02	35.	20.0
300.	268.4	.963	1.27	.96-03	35.	20.9
350.	268.1	.957	1.26	.92-03	34.	21.7
400.	267.8	.951	1.25	.88-03	33.	22.5
450.	267.5	.945	1.25	.85-03	32.	23.2
500.	267.1	.939	1.24	.81-03	31.	23.8
550.	266.8	.933	1.23	.78-03	31.	24.3
600.	266.5	.927	1.23	.74-03	30.	24.9
650.	266.2	.922	1.22	.71-03	29.	25.4
700.	265.8	.916	1.22	.68-03	28.	25.9
750.	265.5	.910	1.21	.65-03	28.	26.3
800.	265.2	.905	1.20	.62-03	27.	26.7
850.	264.9	.899	1.20	.60-03	26.	27.1
900.	264.5	.894	1.19	.57-03	26.	27.5
950.	264.2	.888	1.19	.55-03	25.	27.9
1000.	263.9	.883	1.18	.52-03	24.	28.3
1050.	263.6	.877	1.17	.50-03	24.	28.6
1100.	263.2	.872	1.17	.48-03	23.	29.0
1150.	262.9	.866	1.16	.46-03	23.	29.3
1200.	262.6	.861	1.16	.44-03	22.	29.6
1250.	262.3	.856	1.15	.42-03	22.	29.9
1300.	261.9	.851	1.15	.40-03	21.	30.2
1350.	261.6	.845	1.14	.38-03	20.	30.5
1400.	261.3	.840	1.14	.36-03	20.	30.8
1450.	261.0	.835	1.13	.35-03	19.	31.0
1500.	260.6	.830	1.12	.33-03	19.	31.3
1550.	260.3	.825	1.12	.32-03	18.	31.5
1600.	260.0	.820	1.11	.30-03	18.	31.8
1650.	259.7	.815	1.11	.29-03	17.	32.0
1700.	259.3	.810	1.10	.28-03	17.	32.3
1750.	259.0	.805	1.10	.26-03	17.	32.5
1800.	258.7	.800	1.09	.25-03	16.	32.7
1850.	258.4	.795	1.09	.24-03	16.	33.0
1900.	258.0	.791	1.08	.23-03	15.	33.2
1950.	257.7	.786	1.08	.22-03	15.	33.4
2000.	257.4	.781	1.07	.21-03	15.	33.6

TABLE 5

Typical Ambient Conditions as Functions of Altitude, 270.4°k, 40% Relative Humidity, High Velocity

A TEMPERATURE AND WIND SPEED-RELATIVE HUMIDITY OCCURRENCES:

WIND	0-4 M.P.H.						5-14 M.P.H.						15-24 M.P.H.						25 M.P.H. AND OVER						TOTAL OBS.
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
104/100	1	+					3	2						1											7
99/95	2	3	+				6	23	4				1	6	+					+					43
94/90	3	14	5				14	64	47				2	15	7					+	+				192
89/85	3	15	27	2	+		16	101	132	6	+		2	23	24	1				1	+				355
84/80	3	24	46	26	8	+	15	114	164	62	9	+	7	22	33	7	1			1	1				541
79/75	2	23	53	43	53	16	11	110	138	102	91	20	6	21	30	14	8	1	+	1	2	+			742
74/70	2	14	53	48	74	88	14	76	124	82	106	103	6	19	30	13	9	4	+	1	2	1	+	+	869
69/65	3	12	35	46	76	73	11	56	106	73	80	81	6	21	27	20	13	7	+	1	3	1	1	+	758
64/60	1	11	26	33	75	63	10	68	62	64	72	71	7	23	26	19	20	13	1	1	1	1	1	1	673
59/55	2	13	23	29	44	62	6	78	80	51	69	82	6	29	22	17	17	20	+	3	1	2	1	1	654
54/50	1	11	26	22	40	52	5	67	115	49	63	70	2	30	27	12	13	13	+	1	1	+	+	+	619
49/45	+	9	31	23	33	44	2	55	128	59	66	70	1	23	35	14	18	16	+	+	1	1	1	1	634
44/40	+	6	25	25	30	39	1	45	135	85	73	71	1	19	37	22	22	15		1	1	1	1	+	649
39/35		5	23	25	34	40	+	27	136	105	95	89		12	36	25	27	20		+	1	1	+	+	703
34/30		5	25	24	35	35	+	19	131	132	101	56	+	6	34	22	19	12			+	+	1	+	631
29/25		2	14	17	26	19	+	10	77	55	43	12		4	21	14	6	4			1		+		532
24/20		1	8	12	13	6		8	42	34	12	4	+	4	16	6	3	1			+	+			169
19/15		1	+	5	9	3		6	27	14	10	1		2	12	4	2			+	1				97
14/10		1	3	3	2			2	12	7	3			2	9	2	+				+				45
09/05			1	2	2			+	10	4	+			+	4	2									25
04/00			1	+	1			+	4	1	+				1	1									8
-01/-05				+	+				1	1	+														3
-06/-10				+					+	+	1														1
-11/-15										+															+
-16/-20											+														+
TOTAL	23	170	436	387	360	345	114	550	1482	545	655	720	45	280	425	213	179	124	2	12	17	8	6	[illegible]	58767

In Tables A and C, occurrences are for the average year (10-year total divided by 10). Values are rounded to the nearest whole number, but not adjusted to make their sums exactly equal to column or row totals. "+" indicates more than 0 but less than 0.5.

C OCCURRENCES OF PRECIPITATION AMOUNTS:

INTENSITIES	FREQUENCY OF OCCURRENCE FOR EACH HOUR OF THE DAY																								NO. OF DAYS
	A.M. HOUR ENDING AT												P.M. HOUR ENDING AT												
	1	2	3	4	5	6	7	8	9	[illegible]	[illegible]	[illegible]	1	2	3	4	5	6	7	8	9	10	11	MD	[illegible]
TRACE	30	28	25	32	31	32	36	35	34	35	31	33	34	33	30	28	27	25	26	29	26	28	29	27	57
[illegible]	6	7	6	7	8	8	6	6	7	5	6	7	6	5	8	7	7	8	6	6	5	7	6	7	11
[illegible]	12	12	13	14	14	12	13	14	13	14	14	14	14	12	13	12	12	12	13	12	12	11	12	12	32
[illegible]	3	4	5	4	4	5	4	5	5	4	3	4	3	2	3	4	4	4	3	3	3	4	3	3	26
[illegible]	1	1	1	1	1	1	1	1	1	1	+	1	1	1	1	1	1	1	1	1	1	1	1	1	22
[illegible]	1	+	+	+	+	1	+	+	+	+	+	+	+	1	+	+	+	+	+	+	+	+	+	+	19
[illegible]	+	+				+	+	+								+					+			+	8
[illegible]																									1
TOTAL	52	53	55	57	57	59	62	61	61	59	55	58	56	54	55	53	51	51	49	51	49	51	51	51	277

D PERCENTAGE FREQUENCIES OF CEILING-VISIBILITY:

VISIBILITY (MILES)	CEILING (FEET)									TOT
	0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	OVER [illegible]	
0 TO 1/8	.1	+	+	+		+			+	.2
3/16 TO 3/8	+	+	+	+	+	+			+	.2
1/2 TO 3/4		.1	.1	.2	+	+	+	+	+	.4
1 TO 2 1/2		+	.4	1.1	.4	.1	.1	.1	.9	3.2
3 TO		+	.1	2.0	2.6	1.0	1.3	1.2	9.6	17.9
7 TO 15			+	.6	3.9	4.1	6.0	[illegible]	[illegible]	78.1
20 TO 30										
35 OR MORE										
TOTAL	.1	.2	.7	4.0	7.0	5.9	7.4	7.9	67.5	100

B PERCENTAGE FREQUENCIES OF WIND DIRECTION AND SPEED

DIRECTION	[illegible]									
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
N	[illegible]	[illegible]	[illegible]	[illegible]	.4	+			[illegible]	[illegible]
NNE	.4	1.3	[illegible]	.7	.1	+			[illegible]	[illegible]
NE	1.1	2.2	[illegible]	[illegible]	+		+		[illegible]	[illegible]
ENE	.2	.7	.7	[illegible]	+				[illegible]	[illegible]
E	.6	1.2	.3	[illegible]	+				[illegible]	[illegible]
ESE	.4	.6	.4	[illegible]	+				[illegible]	[illegible]
SE	2.6	[illegible]	[illegible]	[illegible]	+	+	+		[illegible]	[illegible]
SSE	1.2	[illegible]	[illegible]	[illegible]	[illegible]	+	+		[illegible]	[illegible]
S	1.5	[illegible]	[illegible]	[illegible]	[illegible]	.1	+	+	[illegible]	[illegible]
SSW	.3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	+		[illegible]	[illegible]
SW	.7	1.9	[illegible]	[illegible]	[illegible]	.1	+	+	[illegible]	[illegible]
WSW	.2	[illegible]	[illegible]	[illegible]	.2	.1	+	+	[illegible]	[illegible]
W	.5	[illegible]	[illegible]	[illegible]	[illegible]	+	+		[illegible]	[illegible]
WNW	.3	[illegible]	[illegible]	[illegible]	.3	.1	+		[illegible]	[illegible]
NW	.7	[illegible]	[illegible]	[illegible]	.3	+	+		[illegible]	[illegible]
NNW	.2	[illegible]	[illegible]	[illegible]	[illegible]	+			[illegible]	
CALM	4.7								[illegible]	
TOTAL	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	+	[illegible]	[illegible]

E PERCENTAGE FREQUENCIES OF SKY COVER, WIND, AND RELATIVE HUMIDITY:

HOUR OF DAY	CLOUDS SCALE 0-10			WIND SPEED M.P.H.				RELATIVE HUMIDITY %					
	0-3	4-7	8-10	0-3	4-12	13-24	25 & OVER	0-29	30-49	50-69	70-79	80-89	90-100
00	51	9	[illegible]	[illegible]	[illegible]	[illegible]	+	+	2	[illegible]	[illegible]	[illegible]	[illegible]
01	50	9	[illegible]	27	[illegible]	[illegible]	+	+	2	[illegible]	23	[illegible]	[illegible]
02	49	5	[illegible]	[illegible]	[illegible]	[illegible]	1	+	1	[illegible]	[illegible]	[illegible]	[illegible]
03	48	9	43	[illegible]	[illegible]	15	+	+	1	[illegible]	[illegible]	[illegible]	[illegible]
04	45	11	[illegible]	[illegible]	[illegible]	[illegible]	+		1	12	[illegible]	[illegible]	[illegible]
05	41	13	[illegible]	[illegible]	[illegible]	[illegible]	+		1	13	[illegible]	[illegible]	[illegible]
06	37	13	[illegible]	[illegible]	[illegible]	[illegible]	+		1	[illegible]	[illegible]	[illegible]	[illegible]
07	36	12	[illegible]	[illegible]	[illegible]	[illegible]	+		2	[illegible]	[illegible]	[illegible]	[illegible]
08	36	[illegible]	52	[illegible]	[illegible]	[illegible]	+	+	6	38	[illegible]	[illegible]	[illegible]
09	36	[illegible]	52	[illegible]	[illegible]	[illegible]	+	+	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
10	35	15	51	[illegible]	[illegible]	[illegible]	1	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
11	34	17	[illegible]	[illegible]	[illegible]	[illegible]	1	3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
12	32	[illegible]	[illegible]	[illegible]	[illegible]	37	1	5	37	[illegible]	[illegible]		[illegible]
13	32	20	[illegible]	7	[illegible]	[illegible]	1	7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
14	[illegible]	16	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
15	33	17	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
16	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
17	37	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
18	[illegible]	13	[illegible]	[illegible]	[illegible]	[illegible]	+	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
19	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	+	+	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
20	[illegible]	12	[illegible]	[illegible]	[illegible]	[illegible]	+	+	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
21	49	11	[illegible]	[illegible]	[illegible]	[illegible]	+	+	[illegible]	35	[illegible]	[illegible]	[illegible]
22	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	+	+	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
23	51	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	+	+	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
AVG	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

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TABLE 6

Weather Data Summary, Standiford Airport, Louisville, Kentucky, 1951-1961

TEMPERATURE-VELOCITY-HUMIDITY FREQUENCIES

WIND VELOCITY 0-4 MPH.

RELATIVE HUMIDITY TEMPERATURE DEG; F	0 -30	30 -50	50 -70	70 -80	80 -90	90 -100
-20-15	.0000	.0001	.0006	.0006	.0006	.0006
15 -40	.0000	.0016	.0084	.0097	.0140	.0124
40 -60	.0003	.0041	.0120	.0113	.0168	.0225
60 -80	.0009	.0068	.0196	.0196	.0317	.0274
80 -100	.0014	.0067	.0091	.0034	.0009	.0000

WIND VELOCITY 5-14 MPH.

RELATIVE HUMIDITY TEMPERATURE DEG; F	0 -30	30 -50	50 -70	70 -80	80 -90	90 -100
-20-15	.0002	.0031	.0015	.0005	.0000	.0000
15 -40	.0000	.0078	.0471	.0352	.0248	.0185
40 -60	.0016	.0279	.0522	.0273	.0311	.0134
60 -80	.0052	.0354	.0513	.0366	.0398	.0114
80 -100	.0062	.0370	.0391	.0078	.0010	.0000

WIND VELOCITY 15-24 MPH.

RELATIVE HUMIDITY TEMPERATURE DEG. F	0 -30	30 -50	50 -70	70 -80	80 -90	90 -100
-20-15	.0002	.0016	.0006	.0000	.0000	.0000
15 -40	.0000	.0032	.0136	.0081	.0065	.0042
40 -60	.0011	.0115	.0138	.0074	.0040	.0073
60 -80	.0029	.0096	.0129	.0075	.0057	.0029
80 -100	.0014	.0076	.0073	.0009	.0001	.0000

WIND VELOCITY GT.25 MPH.

RELATIVE HUMIDITY TEMPERATURE DEG; F	0 -30	30 -50	50 -70	70 -80	80 -90	90 -100
-20-15	.0000	.0000	.0000	.0000	.0000	.0000
15 -40	.0000	.0000	.0003	.0001	.0001	.0000
40 -60	.0000	.0006	.0005	.0005	.0003	.0002
60 -80	.0001	.0005	.0009	.0003	.0002	.0001
80 -100	.0000	.0002	.0001	.0000	.0000	.0000

TABLE 7

Joint Frequency Distributions, Temperature-Velocity-Humidity, Standiford Field, Louisville, Kentucky, 1951-1961

TA-94

TOTAL VELOCITY-DIRECTION FREQUENCIES

WIND VELOCITY MPH.	0-4	5-14	15-24	GT.25
DIRECTION				
N	.0035	.0655	.0091	.0003
NNE	.0046	.0521	.0049	.0003
NE	.0044	.0443	.0028	.0000
ENE	.0050	.0268	.0008	.0000
E	.0065	.0499	.0010	.0000
ESE	.0074	.0371	.0000	.0000
SE	.0134	.0571	.0004	.0000
SSE	.0093	.0534	.0005	.0000
S	.0130	.1148	.0155	.0003
SSW	.0013	.0357	.0155	.0000
SW	.0010	.0334	.0109	.0000
WSW	.0019	.0406	.0084	.0003
W	.0062	.0603	.0135	.0000
WNW	.0036	.0393	.0134	.0003
NW	.0021	.0463	.0149	.0000
NNW	.0023	.0152	.0052	.0000

TABLE 8

Velocity-Direction Frequency Distribution--All Stabilities, Standiford Field, Louisville, Kentucky

STABILITY CLASS A

WIND VELOCITY MPH.	0-4	5-14	15-24	GT.25
N	.0001	.0003	.0000	.0000
NNE	.0001	.0003	.0000	.0000
NE	.0000	.0003	.0000	.0000
ENE	.0007	.0006	.0000	.0000
E	.0007	.0006	.0000	.0000
ESE	.0000	.0000	.0000	.0000
SE	.0004	.0010	.0000	.0000
SSE	.0000	.0000	.0000	.0000
S	.0000	.0000	.0000	.0000
SSW	.0000	.0000	.0000	.0000
SW	.0000	.0000	.0000	.0000
WSW	.0002	.0006	.0000	.0000
W	.0000	.0000	.0000	.0000
WNW	.0006	.0003	.0000	.0000
NW	.0000	.0000	.0000	.0000
NNW	.0000	.0000	.0000	.0000

STABILITY CLASS B

WIND VELOCITY MPH.	0-4	5-14	15-24	GT.25
N	.0004	.0040	.0000	.0000
NNE	.0004	.0044	.0000	.0000
NE	.0000	.0027	.0000	.0000
ENE	.0007	.0030	.0000	.0000
E	.0007	.0043	.0000	.0000
ESE	.0007	.0036	.0000	.0000
SE	.0014	.0043	.0000	.0000
SSE	.0014	.0037	.0000	.0000
S	.0004	.0033	.0000	.0000
SSW	.0000	.0009	.0000	.0000
SW	.0000	.0019	.0000	.0000
WSW	.0003	.0019	.0000	.0000
W	.0007	.0043	.0000	.0000
WNW	.0007	.0012	.0000	.0000
NW	.0003	.0016	.0000	.0000
NNW	.0007	.0000	.0000	.0000

TABLE 9

Velocity-Direction Frequency Distributions, A & B Stabilities, Standiford Field, Louisville, Kentucky

STABILITY CLASS C

WIND VELOCITY MPH.	0-4	5-14	15-24	GT.25
N	.0001	.0075	.0001	.0000
NNE	.0001	.0057	.0007	.0000
NE	.0001	.0077	.0007	.0000
ENE	.0001	.0047	.0000	.0000
E	.0009	.0051	.0000	.0000
ESE	.0094	.0040	.0000	.0000
SE	.0015	.0055	.0001	.0000
SSE	.0001	.0050	.0000	.0000
S	.0013	.0124	.0005	.0000
SSW	.0000	.0024	.0007	.0000
SW	.0000	.0050	.0011	.0000
WSW	.0000	.0053	.0007	.0000
W	.0009	.0053	.0007	.0000
WNW	.0004	.0031	.0005	.0000
NW	.0000	.0029	.0003	.0000
NNW	.0000	.0007	.0001	.0000

STABILITY CLASS D

WIND VELOCITY MPH.	0-4	5-14	15-24	GT.25
N	.0007	.0439	.0590	.0003
NNE	.0011	.0204	.0042	.0003
NE	.0013	.0213	.0022	.0000
ENE	.0009	.0158	.0000	.0000
E	.0006	.0246	.0010	.0000
ESE	.0020	.0156	.0000	.0000
SE	.0019	.0220	.0003	.0000
SSE	.0018	.0243	.0005	.0000
S	.0008	.0609	.0150	.0003
SSW	.0001	.0201	.0148	.0000
SW	.0004	.0200	.0078	.0000
WSW	.0004	.0245	.0077	.0003
W	.0011	.0372	.0129	.0000
WNW	.0000	.0243	.0129	.0003
NW	.0009	.0344	.0146	.0000
NNW	.0001	.0138	.0150	.0000

TABLE 10
Velocity-Direction Frequency Distributions, C & D Stabilities, Standiford, Field, Louisville, Kentucky

STABILITY CLASS E

WIND VELOCITY MPH.	0-4	5-14	15-24	GT.25
N	.0022	.0078	.0000	.0000
NNE	.0029	.0133	.0000	.0000
NE	.0030	.0126	.0000	.0000
ENE	.0026	.0027	.0000	.0000
E	.0036	.0153	.0000	.0000
ESE	.0055	.0139	.0000	.0000
SE	.0082	.0235	.0000	.0000
SSE	.0060	.0204	.0000	.0000
S	.0105	.0382	.0000	.0000
SSW	.0012	.0037	.0000	.0000
SW	.0036	.0057	.0000	.0000
WSW	.0010	.0082	.0000	.0000
W	.0044	.0115	.0000	.0000
WNW	.0011	.0064	.0000	.0000
NW	.0009	.0074	.0000	.0000
NNW	.0015	.0006	.0000	.0000

TABLE 11

Velocity-Direction Frequency Distribution, E Stability, Standiford Field, Louisville, Kentucky

Group	Representative diameter µm	Droplet size interval µm	Fraction of total mass %
1	50	0-70	22
2	100	70-125	42
3	150	125-175	21
4	190	175-205	7
5	220	205-235	4
6	250	235-260	2
7	275	260-290	.7
8	300	290-310	.5
9	320	310-330	.4
10	350	> 330	.4

TABLE 12

Drift Droplet Size Distribution

```
Z(M)        X(M)     H.VEL.(M/S)   V.VEL.(M/S) MIX.R.(KG/KG)   RADIUS(M)    TEMP(K)   W.M.R.(KG/KG)DENS.(KG/M**3)

  122.        .060       .000          4.13        .642-01        30.5        318.       .471-07       1.06
  140.        1.98       1.09          5.70        .237-01        40.6        294.       .781-02       1.18
  160.        6.48       1.43          5.55        .120-01        57.0        279.       .593-02       1.24
  180.        12.0       1.58          5.28        .758-02        73.9        272.       .412-02       1.27
  200.        18.3       1.67          5.01        .541-02        91.0        267.       .295-02       1.29
  220.        25.3       1.74          4.77        .418-02        108.        264.       .219-02       1.30
  240.        32.8       1.79          4.55        .340-02        126.        262.       .169-02       1.31
  260.        41.0       1.83          4.36        .288-02        143.        261.       .134-02       1.31
  280.        49.6       1.87          4.18        .250-02        160.        260.       .108-02       1.31
  300.        58.8       1.90          4.02        .223-02        177.        259.       .891-03       1.31
  320.        68.4       1.93          3.87        .201-02        194.        258.       .744-03       1.31
  340.        78.7       1.96          3.73        .184-02        211.        258.       .629-03       1.31
  360.        89.4       1.98          3.60        .171-02        228.        257.       .530-03       1.31
  380.        101.       2.01          3.47        .160-02        245.        257.       .461-03       1.31
  400.        113.       2.03          3.34        .151-02        262.        257.       .399-03       1.30
  420.        125.       2.05          3.22        .143-02        279.        256.       .348-03       1.30
  440.        138.       2.07          3.10        .136-02        297.        256.       .305-03       1.30
  460.        152.       2.09          2.98        .130-02        314.        256.       .268-03       1.30
  480.        166.       2.11          2.86        .125-02        331.        255.       .237-03       1.30
  500.        181.       2.13          2.74        .121-02        348.        255.       .211-03       1.29
  520.        197.       2.15          2.62        .117-02        365.        255.       .188-03       1.29
  540.        214.       2.17          2.49        .113-02        383.        255.       .169-03       1.29
  560.        232.       2.18          2.36        .110-02        400.        255.       .152-03       1.29
  580.        251.       2.20          2.22        .107-02        418.        254.       .138-03       1.29
  600.        271.       2.21          2.07        .105-02        436.        254.       .126-03       1.28
  620.        293.       2.22          1.91        .103-02        454.        254.       .116-03       1.28
  640.        318.       2.24          1.74        .101-02        473.        254.       .109-03       1.28
  660.        345.       2.25          1.55        .987-03        492.        254.       .106-03       1.28
  680.        376.       2.26          1.32        .972-03        512.        253.       .985-04       1.27
  700.        414.       2.27          1.05        .959-03        532.        253.       .968-04       1.27
  720.        465.       2.27          .660        .950-03        553.        253.       .978-04       1.27
  736.        634.       2.62          .000        .946-03        555.        253.       .102-03       1.27
  736.        684.       2.62          .000        .898-03        585.        253.       .581-04       1.27
  736.        734.       2.62          .000        .859-03        614.        253.       .208-04       1.27
  736.        784.       2.62          .000        .826-03        642.        253.      -.124-04       1.27
-----------------------------------------------------------------------------------------------------------

MP.=-15.00(C)  E.REL.HUM.=85.(%)  W.VEL.=    .89(M/S)  MAX.VIS.L.=  784.(M)  HEIGHT=  736.(M)  PLUME R.=  642.(M)/)
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TABLE 13
Plume Characteristics, T = -15°C, Relative Humidity = 85%, V = 0.89 m/sec

```
Z(M)          X(M)     H.VEL.(M/S)  V.VEL.(M/S) MIX.R.(KG/KG)  RADIUS(M)    TEMP(K)   W.M.R.(KG/KG)DENS.(KG/M**3)

   122.        .600       .000        4.13        .641-01        30.5        318.        .470-07        1.06
   131.        3.09       3.07        4.66        .418-01        32.7        309.        .277-02        1.10
   141.        11.3       4.73        4.78        .300-01        35.9        303.        .318-02        1.13
   151.        22.2       5.68        4.78        .236-01        39.5        298.        .295-02        1.15
   161.        34.8       6.30        4.73        .196-01        43.3        295.        .259-02        1.16
   171.        48.6       6.74        4.66        .169-01        47.1        293.        .223-02        1.17
   181.        63.5       7.08        4.59        .150-01        50.9        291.        .191-02        1.18
   191.        79.3       7.34        4.50        .135-01        54.7        289.        .163-02        1.19
   201.        96.0       7.56        4.42        .124-01        58.3        288.        .140-02        1.19
   211.        113.       7.75        4.34        .116-01        61.9        287.        .120-02        1.19
   221.        132.       7.91        4.26        .109-01        65.4        286.        .103-02        1.19
   231.        151.       8.06        4.18        .103-01        68.8        286.        .880-03        1.20
   241.        170.       8.19        4.10        .942-02        72.2        285.        .763-03        1.20
   251.        190.       8.30        4.02        .941-02        75.5        285.        .650-03        1.20
   261.        211.       8.41        3.94        .907-02        78.7        284.        .562-03        1.20
   271.        233.       8.51        3.87        .876-02        81.8        284.        .480-03        1.20
   281.        255.       8.60        3.80        .850-02        84.8        283.        .408-03        1.20
   291.        278.       8.69        3.73        .827-02        87.8        283.        .344-03        1.20
   301.        302.       8.77        3.66        .806-02        90.7        283.        .288-03        1.20
   311.        326.       8.85        3.59        .787-02        93.6        282.        .237-03        1.20
   321.        351.       8.92        3.52        .771-02        96.4        282.        .192-03        1.20
   331.        377.       9.00        3.45        .755-02        99.1        282.        .152-03        1.20
   341.        403.       9.06        3.38        .742-02        102.        282.        .116-03        1.20
   351.        430.       9.13        3.31        .729-02        104.        282.        .831-04        1.20
   361.        458.       9.19        3.25        .718-02        107.        281.        .537-04        1.20
   371.        487.       9.25        3.18        .707-02        109.        281.        .271-04        1.20
   379.        511.       9.30        3.12        .699-02        111.        281.        .771-05        1.20
------------------------------------------------------------------------------------------------------------

MP.= 10.00(C)  E.REL.HUM.=85.(%)  W.VEL.=   4.25(M/S)  MAX.VIS.L.=  511.(M)  HEIGHT=  379.(M)  PLUME R.=  111.(M)/)
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TABLE 14

Plume Characteristics, T = 10°C, Relative Humidity = 85%, V = 4.25 m/sec

Z(M)	X(M)	H.VEL.(M/S)	V.VEL.(M/S)	MIX.R.(KG/KG)	RADIUS(M)	TEMP(K)	W.M.R.(KG/KG)	DENS.(KG/M**3)
122.	.000	.000	4.13	.642-01	30.5	318.	.471-07	1.05
131.	8.20	8.53	5.21	.401-01	26.7	307.	.457-02	1.11
141.	21.3	9.87	5.63	.281-01	27.2	300.	.544-02	1.15
151.	40.2	11.8	5.79	.215-01	29.0	294.	.525-02	1.17
161.	61.6	13.1	5.83	.172-01	31.2	290.	.478-02	1.19
171.	84.8	14.0	5.83	.144-01	33.5	287.	.426-02	1.20
181.	110.	14.8	5.79	.123-01	35.8	284.	.378-02	1.21
191.	136.	15.3	5.74	.107-01	38.1	282.	.335-02	1.22
281.	163.	15.8	5.68	.953-02	40.4	280.	.297-02	1.23
211.	191.	16.2	5.61	.859-02	42.6	279.	.264-02	1.23
221.	220.	16.6	5.54	.782-02	44.8	278.	.236-02	1.23
231.	251.	16.9	5.47	.720-02	47.0	277.	.211-02	1.24
241.	282.	17.1	5.40	.667-02	49.1	276.	.190-02	1.24
251.	314.	17.4	5.33	.623-02	51.2	275.	.171-02	1.24
261.	347.	17.6	5.26	.585-02	53.3	274.	.155-02	1.24
271.	381.	17.9	5.19	.553-02	55.3	274.	.140-02	1.25
281.	416.	18.1	5.13	.524-02	57.3	273.	.128-02	1.25
291.	452.	18.2	5.06	.500-02	59.2	273.	.116-02	1.25
381.	488.	18.4	4.99	.478-02	61.1	272.	.106-02	1.25
311.	525.	18.6	4.93	.458-02	62.9	272.	.971-03	1.25
321.	563.	18.8	4.87	.441-02	64.8	272.	.890-03	1.25
331.	602.	18.9	4.80	.425-02	66.5	271.	.816-03	1.25
341.	642.	19.1	4.74	.411-02	68.3	271.	.750-03	1.25
351.	683.	19.2	4.68	.398-02	70.0	271.	.689-03	1.25
361.	724.	19.3	4.62	.386-02	71.7	270.	.634-03	1.25
371.	766.	19.5	4.56	.375-02	73.4	270.	.584-03	1.25
381.	809.	19.6	4.50	.365-02	75.0	270.	.537-03	1.25
391.	853.	19.7	4.44	.356-02	76.6	270.	.495-03	1.25
401.	898.	19.8	4.38	.348-02	78.2	269.	.456-03	1.24
411.	944.	20.0	4.33	.340-02	79.7	269.	.421-03	1.24
421.	990.	20.1	4.27	.333-02	81.2	269.	.388-03	1.24
431.	.104+04	20.2	4.21	.326-02	82.7	269.	.357-03	1.24
441.	.109+04	20.3	4.15	.320-02	84.2	269.	.329-03	1.24
451.	.114+04	20.4	4.10	.314-02	85.6	268.	.303-03	1.24
461.	.119+04	20.5	4.04	.308-02	87.1	268.	.279-03	1.24
471.	.124+04	20.6	3.98	.303-02	88.4	268.	.257-03	1.24
481.	.129+04	20.7	3.93	.298-02	89.8	268.	.236-03	1.24
491.	.134+04	20.8	3.87	.293-02	91.2	268.	.217-03	1.24
501.	.140+04	20.9	3.81	.289-02	92.5	268.	.199-03	1.24

TABLE 15

Plume Characteristics, T = -2.78°C, Relative Humidity = 75%, V = 8.94 m/sec

```
 511.     .145+04    21.0     3.75    .285-02    93.8    268.    .182-03    1.24
 521.     .151+04    21.0     3.69    .281-02    95.0    267.    .167-03    1.24
 531.     .157+04    21.1     3.63    .277-02    96.3    267.    .152-03    1.23
 541.     .162+04    21.2     3.57    .274-02    97.5    267.    .139-03    1.23
 551.     .168+04    21.3     3.51    .270-02    98.7    267.    .126-03    1.23
 561.     .174+04    21.4     3.45    .267-02    99.9    267.    .115-03    1.23
 571.     .181+04    21.5     3.39    .264-02    101.    267.    .104-03    1.23
 581.     .187+04    21.5     3.33    .261-02    102.    267.    .940-04    1.23
 591.     .194+04    21.6     3.27    .258-02    103.    267.    .848-04    1.23
 601.     .200+04    21.7     3.20    .256-02    104.    266.    .763-04    1.23
 611.     .207+04    21.8     3.14    .253-02    105.    266.    .685-04    1.23
 621.     .214+04    21.8     3.07    .251-02    106.    266.    .615-04    1.23
 631.     .221+04    21.9     3.00    .248-02    107.    266.    .547-04    1.22
 641.     .229+04    22.0     2.93    .246-02    108.    266.    .487-04    1.22
 651.     .236+04    22.0     2.86    .244-02    109.    266.    .433-04    1.22
 661.     .244+04    22.1     2.79    .242-02    110.    266.    .384-04    1.22
 671.     .252+04    22.1     2.72    .240-02    111.    266.    .341-04    1.22
 681.     .260+04    22.2     2.64    .238-02    112.    266.    .302-04    1.22
 691.     .269+04    22.3     2.56    .236-02    113.    265.    .269-04    1.22
 701.     .278+04    22.3     2.48    .235-02    114.    265.    .240-04    1.22
 711.     .287+04    22.4     2.40    .233-02    115.    265.    .216-04    1.22
 721.     .296+04    22.4     2.31    .231-02    115.    265.    .197-04    1.21
 731.     .306+04    22.5     2.22    .230-02    116.    265.    .183-04    1.21
 741.     .317+04    22.5     2.13    .229-02    117.    265.    .174-04    1.21
 751.     .327+04    22.6     2.03    .227-02    118.    265.    .169-04    1.21
 761.     .339+04    22.6     1.92    .226-02    118.    265.    .169-04    1.21
 771.     .351+04    22.7     1.81    .225-02    119.    265.    .175-04    1.21
 781.     .364+04    22.7     1.70    .224-02    119.    265.    .186-04    1.21
 791.     .378+04    22.7     1.57    .223-02    120.    265.    .202-04    1.21
 792.     .379+04    26.7     .000    .223-02    120.    265.    .204-04    1.21
 792.     .384+04    26.7     .000    .220-02    121.    265.    .448-05    1.21
-------------------------------------------------------------------------------------------------
MP.= -2.78(C)  E.REL.HUM.=75.(%)  W.VEL.=  8.94(M/S)  MAX.VIS.L.= 3841.(M)  HEIGHT=  792.(M)  PLUME R.=  121.(M)/)
-------------------------------------------------------------------------------------------------
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TABLE 15 (continued)

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Z(M)          X(M)      H.VEL.(M/S)   V.VEL.(M/S) MIX.R.(KG/KG)   RADIUS(M)    TEMP(K)   W.M.R.(KG/KG)DENS.(KG/M**3)

 122.         61.0       22.[illegible]          .000        .641-01      30.5        318.        .470-07      1.06
 32.0         151.       16.[illegible]          .000        .232-01      36.4        298.        .271-02      1.17
 [illegible]  251.       12.[illegible]          .000        .164-01      41.9        293.        .188-02      1.20
 [illegible]  351.       12.1          .000        .136-01      46.2        290.        .139-02      1.21
 [illegible]  451.       12.[illegible]          .000        .120-01      50.6        288.        .104-02      1.22
 [illegible]  551.       12.[illegible]          .000        .109-01      55.0        287.        .787-03      1.22
 [illegible]  651.       12.[illegible]          .000        .102-01      59.1        286.        .596-03      1.23
 [illegible]  751.       12.1          .000        .963-02      63.2        286.        .449-03      1.23
 [illegible]  851.       12.1          .000        .921-02      67.1        285.        .332-03      1.23
 [illegible]  951.       12.[illegible]          .000        .887-02      70.9        285.        .236-03      1.23
 [illegible]  .105+04    12.[illegible]          .000        .863-02      74.7        285.        .160-03      1.23
 [illegible]  .115+04    12.[illegible]          .000        .841-02      78.3        284.        .955-04      1.24
 [illegible]  .125+04    12.[illegible]          .000        .824-02      81.9        284.        .408-04      1.24
 [illegible]  .132+04    12.[illegible]          .000        .813-02      84.9        284.        .725-05      1.24
-----------------------------------------------------------------------------------------------------------------------

E.TEMP.= 10.00(C)  E.REL.HUM.=85.(%)  W.VEL.=12.07(M/S)  MAX.VIS.L.= 1321.(M)  HEIGHT=    0.(M)  PLUME R.=   84.(M)

-----------------------------------------------------------------------------------------------------------------------
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TABLE 16
Plume Characteristics, T = 10°C, Relative Humidity = 85%, V = 12.07 m/sec

```
                        V I S I B L E   L E N G H T   (MT.)

                        WIND VELOCITY    0-4    MPH.
RELATIVE HUMIDITY       0  -30        30 -50        50 -70        70 -80        80 -90        90 -100

TEMPERATURE  DEG. F
   -20-15               99999.         156.          258.          572.          784.          709.
   15 -40               99999.          61.           88.          132.          210.          619.
   40 -60                  19.          25.           36.           54.           81.          159.
   60 -80                   6.           8.           13.           21.           34.           71.
   80 -100                  0.           0.            1.            2.            6.        99999.

                        WIND VELOCITY    5-14   MPH.
RELATIVE HUMIDITY       0  -30        30 -50        50 -70        70 -80        80 -90        90 -100

TEMPERATURE  DEG. F
   -20-15                 750.        1139.         2793.         3439.        99999.        99999.
   15 -40               99999.         365.          548.          916.         2900.         3705.
   40 -60                 106.         141.          211.          324.          511.         3457.
   60 -80                  31.          45.           73.          123.          200.          453.
   80 -100                  0.           1.            3.           12.           30.        99999.

                        WIND VELOCITY    15-24  MPH.
RELATIVE HUMIDITY       0  -30        30 -50        50 -70        70 -80        80 -90        90 -100

TEMPERATURE  DEG. F
   -20-15                2137.        4307.         4799.        99999.        99999.        99999.
   15 -40               99999.         930.         1448.         3841.         4134.         4502.
   40 -60                 259.         545.          523.          825.         1349.         3403.
   60 -80                  77.         109.          181.          306.          507.         1212.
   80 -100                  1.           2.            8.           30.           79.        99999.

                        WIND VELOCITY    GT.25  MPH.
RELATIVE HUMIDITY       0  -30        30 -50        50 -70        70 -80        80 -90        90 -100

TEMPERATURE  DEG. F
   -20-15               99999.       99999.        99999.        99999.        99999.        99999.
   15 -40               99999.       99999.         1491.         2141.         3151.        99999.
   40 -60               99999.         431.          601.          881.         1321.         3071.
   60 -80                 141.         161.          211.          321.          491.         1211.
   80 -100              99999.          71.           81.        99999.        99999.        99999.

99999 - NOT COMPUTED
```

TA-104

TABLE 17

Visible Plume Length

ANNUAL OCCURRENCE OF CONDENSED WATER PLUMES

ALL DIRECTIONS FROM STATION

DISTANCE (METERS)	HRS/YR	PERCENT OF TIME
500	1680	19.2
1000	1500	17.1
2000	1200	13.7
3000	855	10.0
4000	50	0.6

TABLE 18

Annual Occurrence of Condensed Water Plumes

AVERAGE FREQUENCIES OF VISIBLE PLUME LENGTH

HOURS/YEAR

	1	2	5	10	50	100
N	4542.	4542.	4134.	3841.	3427.	1130.
NNE	4542.	4307.	3841.	3705.	2900.	619.
NE	4542.	4134.	3705.	3705.	1448.	548.
ENE	3841.	3705.	3705.	3427.	548.	211.
E	3841.	3705.	3705.	3705.	1448.	548.
ESE	3705.	3705.	3705.	3427.	916.	453.
SE	3705.	3705.	3705.	3705.	2900.	572.
SSE	3705.	3705.	3705.	3705.	2900.	548.
S	4542.	4542.	4542.	4134.	3493.	3427.
SSW	4542.	4542.	4542.	4134.	3427.	930.
SW	4542.	4542.	4307.	4134.	2900.	548.
WSW	4542.	4542.	4134.	3841.	2900.	549.
W	4542.	4542.	4307.	4134.	3427.	1349.
WNW	4542.	4542.	4307.	4134.	3427.	916.
NW	4542.	4542.	4542.	4134.	3427.	1212.
NNW	4542.	4307.	4134.	3705.	548.	210.

TABLE 19

Average Frequencies of Visible Plume

ANNUAL OCCURRENCE OF TOWER INDUCED GROUND LEVEL FOG

ALL DIRECTIONS FROM STATION

DISTANCE (METERS)	HRS/YR	PERCENT OF TIME
500	19.0	0.3
1000	10.5	0.1
2000	less than 1	less than 0.01

TABLE 20

Annual Occurrence of Tower Induced Ground Level Fog

FOGGING LENGHT (MT.)

WIND VELOCITY 0-4 MPH.

RELATIVE HUMIDITY	0 -30	30 -50	50 -70	70 -80	80 -90	90 -100
TEMPERATURE DEG. F						
-20-15	99999.	0.	0.	0.	0.	0.
15 -40	99999.	0.	0.	0.	0.	0.
40 -60	0.	0.	0.	0.	0.	0.
60 -80	0.	0.	0.	0.	0.	0.
80 -100	0.	0.	0.	0.	0.	99999.

WIND VELOCITY 5-14 MPH.

RELATIVE HUMIDITY	0 -30	30 -50	50 -70	70 -80	80 -90	90 -100
TEMPERATURE DEG. F						
-20-15	0.	0.	0.	0.	99999.	99999.
15 -40	99999.	0.	0.	0.	0.	0.
40 -60	0.	0.	0.	0.	0.	0.
60 -80	0.	0.	0.	0.	0.	0.
80 -100	0.	0.	0.	0.	0.	99999.

WIND VELOCITY 15-24 MPH.

RELATIVE HUMIDITY	0 -30	30 -50	50 -70	70 -80	80 -90	90 -100
TEMPERATURE DEG. F						
-20-15	0.	0.	0.	99999.	99999.	99999.
15 -40	99999.	0.	0.	0.	0.	0.
40 -60	0.	0.	0.	0.	0.	0.
60 -80	0.	0.	0.	0.	0.	0.
80 -100	0.	0.	0.	0.	0.	99999.

WIND VELOCITY GT.25 MPH.

RELATIVE HUMIDITY	0 -30	30 -50	50 -70	70 -80	80 -90	90 -100
TEMPERATURE DEG. F						
-20-15	99999.	99999.	99999.	99999.	99999.	99999.
15 -40	99999.	99999.	1340.	1990.	3000.	99999.
40 -60	99999.	280.	450.	230.	1170.	2920.
60 -80	0.	10.	60.	170.	340.	1060.
80 -100	99999.	0.	0.	99999.	99999.	99999.

99999 - NOT COMPUTED

TABLE 21
Fogging Length

AVERAGE FREQUENCIES OF FOGGING LENGTH

	1	2	5	10	50	100	HOURS/YEAR
N	1340.	1040.	280.	0.	0.	0.	
NNE	1340.	1040.	280.	0.	0.	0.	
NE	0.	0.	0.	0.	0.	0.	
ENE	0.	0.	0.	0.	0.	0.	
E	0.	0.	0.	0.	0.	0.	
ESE	0.	0.	0.	0.	0.	0.	
SE	0.	0.	0.	0.	0.	0.	
SSE	0.	0.	0.	0.	0.	0.	
S	1340.	1040.	280.	0.	0.	0.	
SSW	0.	0.	0.	0.	0.	0.	
SW	0.	0.	0.	0.	0.	0.	
WSW	1340.	1040.	280.	0.	0.	0.	
W	0.	0.	0.	0.	0.	0.	
WNW	1340.	1040.	280.	0.	0.	0.	
NW	0.	0.	0.	0.	0.	0.	
NNW	0.	0.	0.	0.	0.	0.	

TABLE 22

Average Frequencies of Fogging

ICING LENGTH (MT.)

WIND VELOCITY 0-4 MPH.

RELATIVE HUMIDITY TEMPERATURE DEG. F	0 -30	30 -50	50 -70	70 -80	80 -90	90 -100
-20-15	99999.	0.	0.	0.	0.	0.
15 -40	99999.	0.	0.	0.	0.	0.
40 -60	0.	0.	0.	0.	0.	0.
60 -80	0.	0.	0.	0.	0.	0.
80 -100	0.	0.	0.	0.	0.	99999.

WIND VELOCITY 5-14 MPH.

RELATIVE HUMIDITY TEMPERATURE DEG. F	0 -30	30 -50	50 -70	70 -80	80 -90	90 -100
-20-15	0.	0.	0.	0.	99999.	99999.
15 -40	99999.	0.	0.	0.	0.	0.
40 -60	0.	0.	0.	0.	0.	0.
60 -80	0.	0.	0.	0.	0.	0.
80 -100	0.	0.	0.	0.	0.	99999.

WIND VELOCITY 15-24 MPH.

RELATIVE HUMIDITY TEMPERATURE DEG. F	0 -30	30 -50	50 -70	70 -80	80 -90	90 -100
-20-15	0.	0.	0.	99999.	99999.	99999.
15 -40	99999.	0.	0.	0.	0.	0.
40 -60	0.	0.	0.	0.	0.	0.
60 -80	0.	0.	0.	0.	0.	0.
80 -100	0.	0.	0.	0.	0.	99999.

WIND VELOCITY GT.25 MPH.

RELATIVE HUMIDITY TEMPERATURE DEG. F	0 -30	30 -50	50 -70	70 -80	80 -90	90 -100
-20-15	99999.	99999.	99999.	99999.	99999.	99999.
15 -40	99999.	99999.	1340.	1990.	3000.	99999.
40 -60	99999.	0.	0.	0.	0.	0.
60 -80	0.	0.	0.	0.	0.	0.
80 -100	99999.	0.	0.	99999.	99999.	99999.

99999 - NOT COMPUTED

TABLE 23

Icing Length

AVERAGE FREQUENCIES OF ICING LENGHT

	1	2	5	10	50	100	HOURS/YEAR
N	0.	0.	0.	0.	0.	0.	
NNE	0.	0.	0.	0.	0.	0.	
NE	0.	0.	0.	0.	0.	0.	
ENE	0.	0.	0.	0.	0.	0.	
E	0.	0.	0.	0.	0.	0.	
ESE	0.	0.	0.	0.	0.	0.	
SE	0.	0.	0.	0.	0.	0.	
SSE	0.	0.	0.	0.	0.	0.	
S	0.	0.	0.	0.	0.	0.	
SSW	0.	0.	0.	0.	0.	0.	
SW	0.	0.	0.	0.	0.	0.	
WSW	0.	0.	0.	0.	0.	0.	
W	0.	0.	0.	0.	0.	0.	
WNW	0.	0.	0.	0.	0.	0.	
NW	0.	0.	0.	0.	0.	0.	
NNW	0.	0.	0.	0.	0.	0.	

TABLE 24

Average Frequencies of Icing

WIND DIRECTION N

DISTANCE MT.	50.	100.	150.	200.	250.	300.	350.	400.	450.	500.
DRIFT DEPOSITION KG/SQKM/MONTH	0.	108.	52.	32.	24.	17.	16.	16.	16.	17.
DISTANCE MT.	600.	700.	800.	900.	1000.	1100.	1200.	1300.	1400.	1500.
DRIFT DEPOSITION KG/SQKM/MONTH	28.	26.	21.	18.	16.	14.	13.	13.	12.	11.
DISTANCE MT.	2000.	2500.	3000.	4000.	5000.	6000.	7000.	8000.	10000.	15000.
DRIFT DEPOSITION KG/SQKM/MONTH	10.	7.	6.	4.	4.	3.	3.	3.	2.	1.

TA-112

WIND DIRECTION NNE

DISTANCE MT.	50.	100.	150.	200.	250.	300.	350.	400.	450.	500.
DRIFT DEPOSITION KG/SQKM/MONTH	0.	145.	70.	43.	33.	23.	20.	21.	22.	23.
DISTANCE MT.	600.	700.	800.	900.	1000.	1100.	1200.	1300.	1400.	1500.
DRIFT DEPOSITION KG/SQKM/MONTH	30.	28.	23.	20.	18.	16.	15.	15.	14.	14.
DISTANCE MT.	2000.	2500.	3000.	4000.	5000.	6000.	7000.	8000.	10000.	15000.
DRIFT DEPOSITION KG/SQKM/MONTH	11.	9.	7.	5.	4.	4.	3.	3.	2.	1.

Table 25: Distributions of Drift Deposition, N & NNE Wind Directions

WIND DIRECTION NE

DISTANCE MT.	50.	100.	150.	200.	250.	300.	350.	400.	450.	500.
DRIFT DEPOSITION KG/SQKM/MONTH	0.	148.	72.	44.	34.	23.	21.	21.	22.	23.
DISTANCE MT.	600.	700.	800.	900.	1000.	1100.	1200.	1300.	1400.	1500.
DRIFT DEPOSITION KG/SQKM/MONTH	29.	27.	22.	19.	17.	16.	15.	14.	14.	13.
DISTANCE MT.	2000.	2500.	3000.	4000.	5000.	6000.	7000.	8000.	10000.	15000.
DRIFT DEPOSITION KG/SQKM/MONTH	11.	9.	7.	4.	4.	4.	3.	3.	2.	1.

WIND DIRECTION ENE

DISTANCE MT.	50.	100.	150.	200.	250.	300.	350.	400.	450.	500.
DRIFT DEPOSITION KG/SQKM/MONTH	0.	140.	66.	40.	31.	21.	19.	19.	20.	21.
DISTANCE MT.	600.	700.	800.	900.	1000.	1100.	1200.	1300.	1400.	1500.
DRIFT DEPOSITION KG/SQKM/MONTH	23.	21.	18.	16.	14.	13.	12.	12.	11.	11.
DISTANCE MT.	2000.	2500.	3000.	4000.	5000.	6000.	7000.	8000.	10000.	15000.
DRIFT DEPOSITION KG/SQKM/MONTH	9.	7.	6.	3.	3.	3.	2.	2.	1.	0.

Table 26: Distributions of Drift Deposition, NE & ENE Wind Directions

WIND DIRECTION E

DISTANCE MT.	50.	100.	150.	200.	250.	300.	350.	400.	450.	500.
DRIFT DEPOSITION KG/SQKM/MONTH	0.	182.	86.	53.	40.	28.	35.	26.	26.	27.
DISTANCE MT.	600.	700.	800.	900.	1000.	1100.	1200.	1300.	1400.	1500.
DRIFT DEPOSITION KG/SQKM/MONTH	34.	31.	26.	23.	21.	19.	18.	17.	16.	15.
DISTANCE MT.	2000.	2500.	3000.	4000.	5000.	6000.	7000.	8000.	10000.	15000.
DRIFT DEPOSITION KG/SQKM/MONTH	13.	10.	8.	5.	4.	4.	3.	3.	2.	1.

WIND DIRECTION ESE

DISTANCE MT.	50.	100.	150.	200.	250.	300.	350.	400.	450.	500.
DRIFT DEPOSITION KG/SQKM/MONTH	0.	298.	143.	87.	67.	47.	41.	43.	44.	45.
DISTANCE MT.	600.	700.	800.	900.	1000.	1100.	1200.	1300.	1400.	1500.
DRIFT DEPOSITION KG/SQKM/MONTH	48.	43.	36.	32.	30.	27.	26.	25.	24.	24.
DISTANCE MT.	2000.	2500.	3000.	4000.	5000.	6000.	7000.	8000.	10000.	15000.
DRIFT DEPOSITION KG/SQKM/MONTH	21.	16.	12.	7.	6.	5.	5.	4.	3.	1.

Table 27: Distributions of Drift Deposition, E & ESE Wind Directions

WIND DIRECTION SE

DISTANCE MT.	50.	100.	150.	200.	250.	300.	350.	400.	450.	500.
DRIFT DEPOSITION KG/SQKM/MONTH	0.	405.	194.	118.	91.	63.	56.	58.	59.	61.
DISTANCE MT.	600.	700.	800.	900.	1000.	1100.	1200.	1300.	1400.	1500.
DRIFT DEPOSITION KG/SQKM/MONTH	66.	60.	50.	45.	41.	38.	36.	35.	34.	33.
DISTANCE MT.	2000.	2500.	3000.	4000.	5000.	6000.	7000.	8000.	10000.	15000.
DRIFT DEPOSITION KG/SQKM/MONTH	28.	22.	17.	9.	8.	7.	6.	5.	4.	1.

WIND DIRECTION SSE

DISTANCE MT.	50.	100.	150.	200.	250.	300.	350.	400.	450.	500.
DRIFT DEPOSITION KG/SQKM/MONTH	0.	290.	140.	86.	66.	46.	41.	42.	43.	45.
DISTANCE MT.	600.	700.	800.	900.	1000.	1100.	1200.	1300.	1400.	1500.
DRIFT DEPOSITION KG/SQKM/MONTH	51.	46.	38.	34.	31.	28.	27.	26.	25.	24.
DISTANCE MT.	2000.	2500.	3000.	4000.	5000.	6000.	7000.	8000.	10000.	15000.
DRIFT DEPOSITION KG/SQKM/MONTH	21.	16.	13.	7.	7.	6.	5.	4.	3.	1.

Table 28: Distributions of Drift Deposition, SE & SSE Wind Directions

```
                              ****************************
                              *  WIND DIRECTION  S       *
                              *                          *
**************************************************************************************************
*                      *                                                                        *
* DISTANCE  MT.        *    50.    100.    150.    200.    250.    300.    360.    400.    450.    500. *
*                      *                                                                        *
* DRIFT DEPOSITION     *     0.    432.    211.    129.     99.     69.     61.     63.     65.     68. *
*   KG/SQKM/MONTH      *                                                                        *
**************************************************************************************************
*                      *                                                                        *
* DISTANCE  MT.        *   600.    700.    800.    900.   1000.   1100.   1200.   1300.   1400.   1500. *
*                      *                                                                        *
* DRIFT DEPOSITION     *    84.     77.     64.     56.     50.     47.     49.     42.     41.     39. *
*   KG/SQKM/MONTH      *                                                                        *
**************************************************************************************************
*                      *                                                                        *
* DISTANCE  MT.        *  2000.   2500.   3000.   4000.   5000.   6000.   7000.   8000.  10000.  15000. *
*                      *                                                                        *
* DRIFT DEPOSITION     *    34.     26.     21.     12.     11.     10.      9.      8.      6.      2. *
*   KG/SQKM/MONTH      *                                                                        *
**************************************************************************************************

                              ****************************
                              *  WIND DIRECTION  SSW     *
                              *                          *
**************************************************************************************************
*                      *                                                                        *
* DISTANCE  MT.        *    50.    100.    150.    200.    250.    300.    350.    400.    450.    500. *
*                      *                                                                        *
* DRIFT DEPOSITION     *     0.     46.     23.     14.     11.      7.      7.      7.      7.      7. *
*   KG/SQKM/MONTH      *                                                                        *
**************************************************************************************************
*                      *                                                                        *
* DISTANCE  MT.        *   600.    700.    800.    900.   1000.   1100.   1200.   1300.   1400.   1500. *
*                      *                                                                        *
* DRIFT DEPOSITION     *    14.     13.     10.      9.      8.      7.      6.      6.      6.      5. *
*   KG/SQKM/MONTH      *                                                                        *
**************************************************************************************************
*                      *                                                                        *
* DISTANCE  MT.        *  2000.   2500.   3000.   4000.   5000.   6000.   7000.   8000.  10000.  15000. *
*                      *                                                                        *
* DRIFT DEPOSITION     *     5.      4.      3.      2.      2.      2.      2.      1.      1.      1. *
*   KG/SQKM/MONTH      *                                                                        *
**************************************************************************************************
```

Table 29: Distributions of Drift Deposition, S & SSW Wind Directions

WIND DIRECTION SW

DISTANCE MT.	50.	100.	150.	200.	250.	300.	350.	400.	450.	500.
DRIFT DEPOSITION KG/SQKM/MONTH	0.	33.	16.	10.	8.	5.	5.	5.	5.	5.
DISTANCE MT.	600.	700.	800.	900.	1000.	1100.	1200.	1300.	1400.	1500.
DRIFT DEPOSITION KG/SQKM/MONTH	11.	10.	9.	7.	6.	5.	5.	5.	4.	4.
DISTANCE MT.	2000.	2500.	3000.	4000.	5000.	6000.	7000.	8000.	10000.	15000.
DRIFT DEPOSITION KG/SQKM/MONTH	4.	3.	2.	2.	2.	1.	1.	1.	1.	1.

WIND DIRECTION WSW

DISTANCE MT.	50.	100.	150.	200.	250.	300.	350.	400.	450.	500.
DRIFT DEPOSITION KG/SQKM/MONTH	0.	54.	26.	16.	12.	8.	7.	8.	8.	8.
DISTANCE MT.	600.	700.	800.	900.	1000.	1100.	1200.	1300.	1400.	1500.
DRIFT DEPOSITION KG/SQKM/MONTH	15.	14.	12.	10.	9.	8.	7.	7.	6.	6.
DISTANCE MT.	2000.	2500.	3000.	4000.	5000.	6000.	7000.	8000.	10000.	15000.
DRIFT DEPOSITION KG/SQKM/MONTH	5.	4.	3.	2.	2.	2.	2.	2.	1.	1.

Table 30: Distributions of Drift Deposition, SW & WSW Wind Directions

WIND DIRECTION W

DISTANCE MT.	50.	100.	150.	200.	250.	300.	350.	400.	450.	500.
DRIFT DEPOSITION KG/SQKM/MONTH	0.	200.	97.	59.	46.	32.	38.	29.	30.	31.

DISTANCE MT.	600.	700.	800.	900.	1000.	1100.	1200.	1300.	1400.	1500.
DRIFT DEPOSITION KG/SQKM/MONTH	40.	36.	30.	26.	23.	22.	20.	20.	19.	18.

DISTANCE MT.	2000.	2500.	3000.	4000.	5000.	6000.	7000.	8000.	10000.	15000.
DRIFT DEPOSITION KG/SQKM/MONTH	16.	12.	10.	6.	5.	5.	4.	4.	3.	1.

WIND DIRECTION WNW

DISTANCE MT.	50.	100.	150.	200.	250.	300.	350.	400.	450.	500.
DRIFT DEPOSITION KG/SQKM/MONTH	0.	88.	40.	24.	18.	13.	11.	12.	12.	12.

DISTANCE MT.	600.	700.	800.	900.	1000.	1100.	1200.	1300.	1400.	1500.
DRIFT DEPOSITION KG/SQKM/MONTH	19.	18.	15.	13.	11.	10.	9.	9.	8.	8.

DISTANCE MT.	2000.	2500.	3000.	4000.	5000.	6000.	7000.	8000.	10000.	15000.
DRIFT DEPOSITION KG/SQKM/MONTH	6.	5.	4.	3.	2.	2.	2.	2.	1.	1.

Table 31: Distributions of Drift Deposition, W & WNW Wind Directions

```
                              ************************
                              *  WIND DIRECTION  NW  *
                              *                      *
*************************************************************************************************************
* DISTANCE  MT.        *     50.     100.     150.     200.     250.     300.     350.     400.     450.     500. *
* DRIFT DEPOSITION     *      0.      63.      30.      18.      14.      10.       9.       9.       9.      10. *
*   KG/SQKM/MONTH      *
*************************************************************************************************************
* DISTANCE  MT.        *    600.     700.     800.     900.    1000.    1100.    1200.    1300.    1400.    1500. *
* DRIFT DEPOSITION     *     18.      17.      14.      11.      10.       9.       8.       8.       7.       7. *
*   KG/SQKM/MONTH      *
*************************************************************************************************************
* DISTANCE  MT.        *   2000.    2500.    3000.    4000.    5000.    6000.    7000.    8000.   10000.   15000. *
* DRIFT DEPOSITION     *      6.       4.       4.       3.       2.       2.       2.       2.       2.       1. *
*   KG/SQKM/MONTH      *
*************************************************************************************************************
```

Table 32: Distributions of Drift Deposition, NW & NNW Wind Directions

```
                              *************************
                              *  WIND DIRECTION  NNW  *
                              *                       *
*************************************************************************************************************
* DISTANCE  MT.        *     50.     100.     150.     200.     250.     300.     350.     400.     450.     500. *
* DRIFT DEPOSITION     *      0.      67.      32.      20.      15.      10.       9.      10.      10.      10. *
*   KG/SQKM/MONTH      *
*************************************************************************************************************
* DISTANCE  MT.        *    600.     700.     800.     900.    1000.    1100.    1200.    1300.    1400.    1500. *
* DRIFT DEPOSITION     *     12.      11.       9.       8.       7.       7.       6.       6.       6.       6. *
*   KG/SQKM/MONTH      *
*************************************************************************************************************
* DISTANCE  MT.        *   2000.    2500.    3000.    4000.    5000.    6000.    7000.    8000.   10000.   15000. *
* DRIFT DEPOSITION     *      5.       4.       3.       2.       1.       1.       1.       1.       1.       0. *
*   KG/SQKM/MONTH      *
*************************************************************************************************************
```

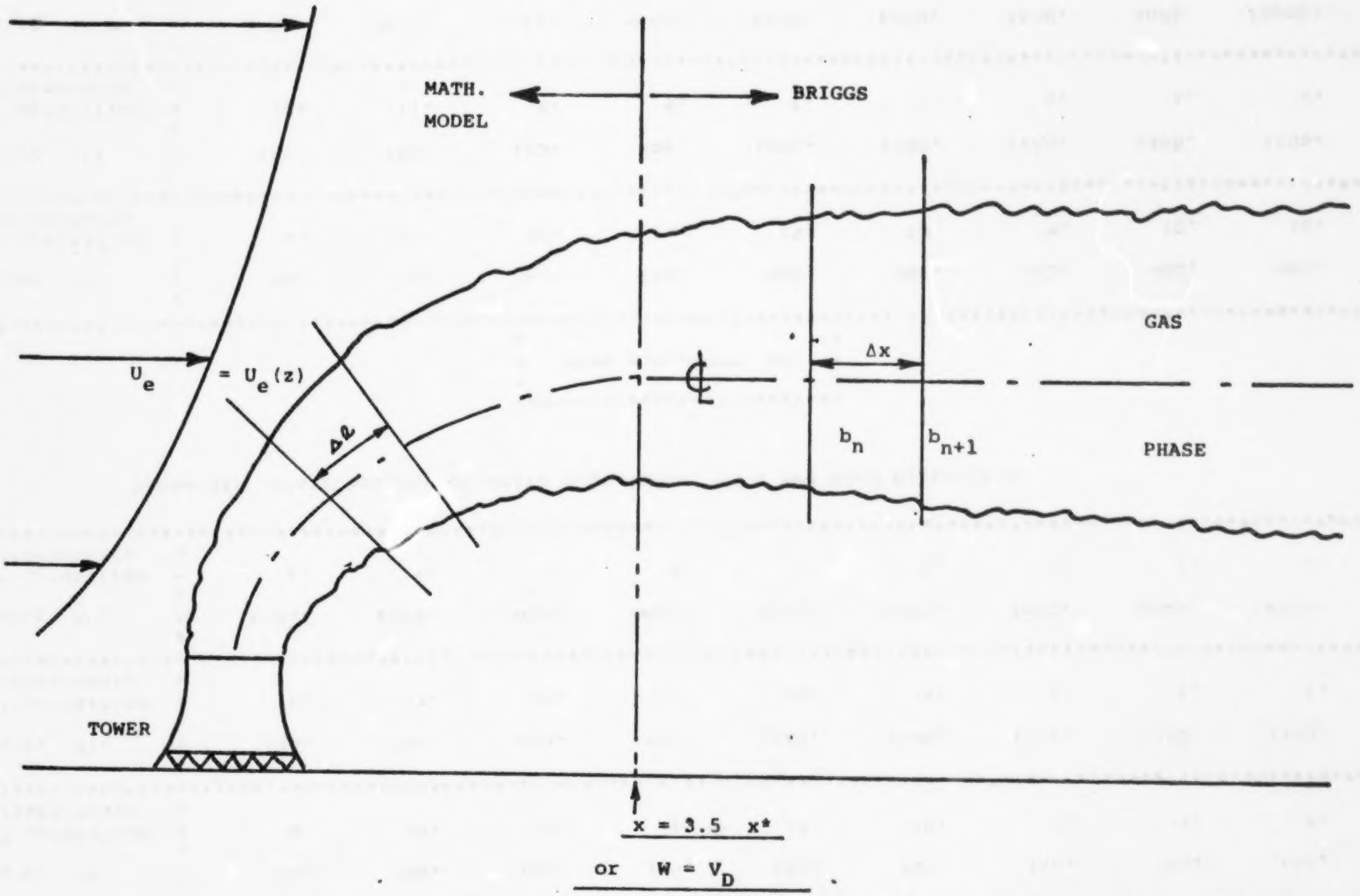

MATH.
MODEL
BRIGGS
GAS
PHASE
U_e
$= U_e(z)$
$\Delta \ell$
Δx
b_n
b_{n+1}
TOWER
$x = 3.5 \quad x^*$
or $W = V_D$

Fig. 1 Sketch of Plume Indicating Computational Scheme for Calculating Center Line Trajectory

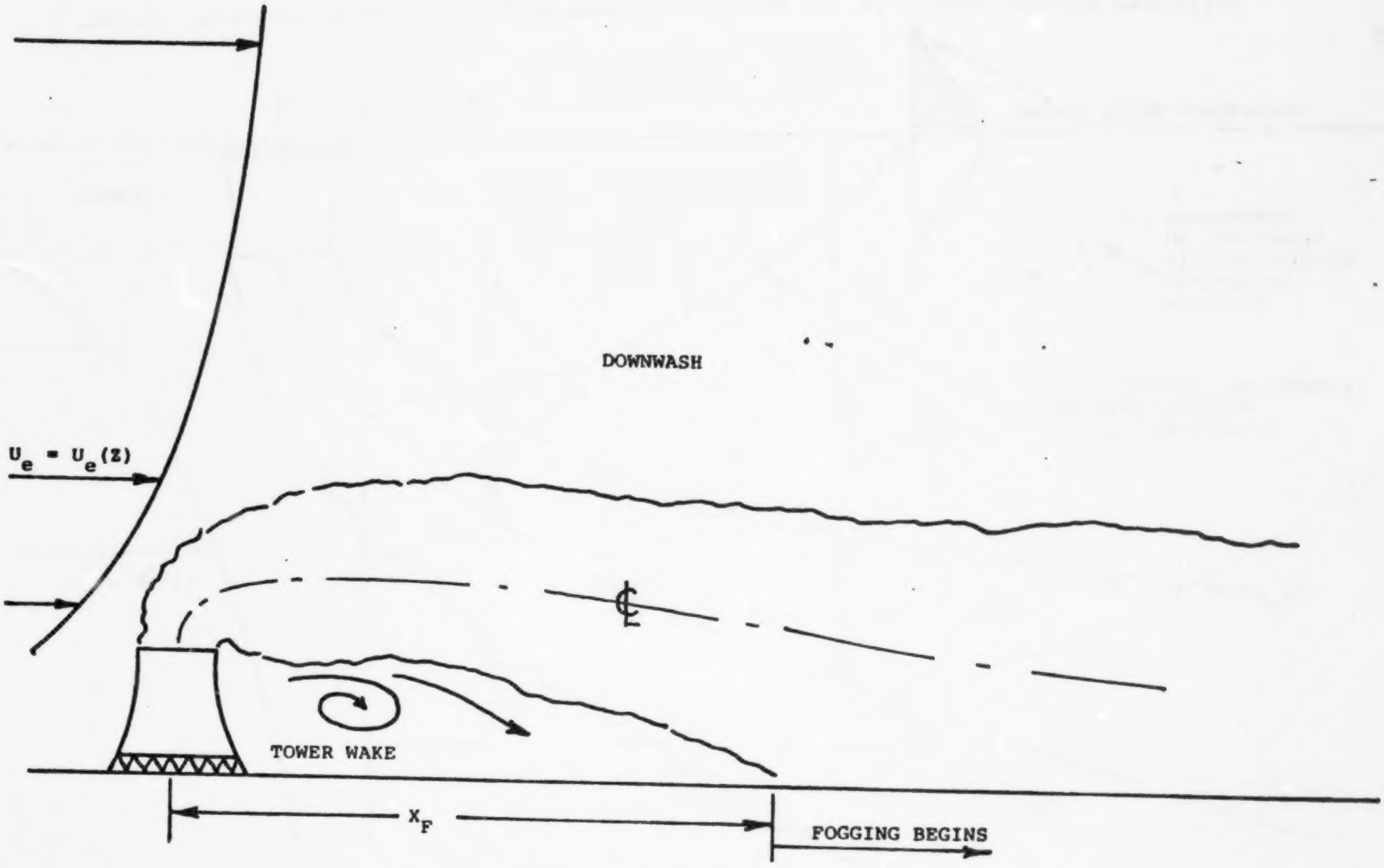

$U_e = U_e(Z)$
DOWNWASH
℄
TOWER WAKE
X_F
FOGGING BEGINS

Fig. 2 Sketch of Plume Under Ground Level Fogging Conditions

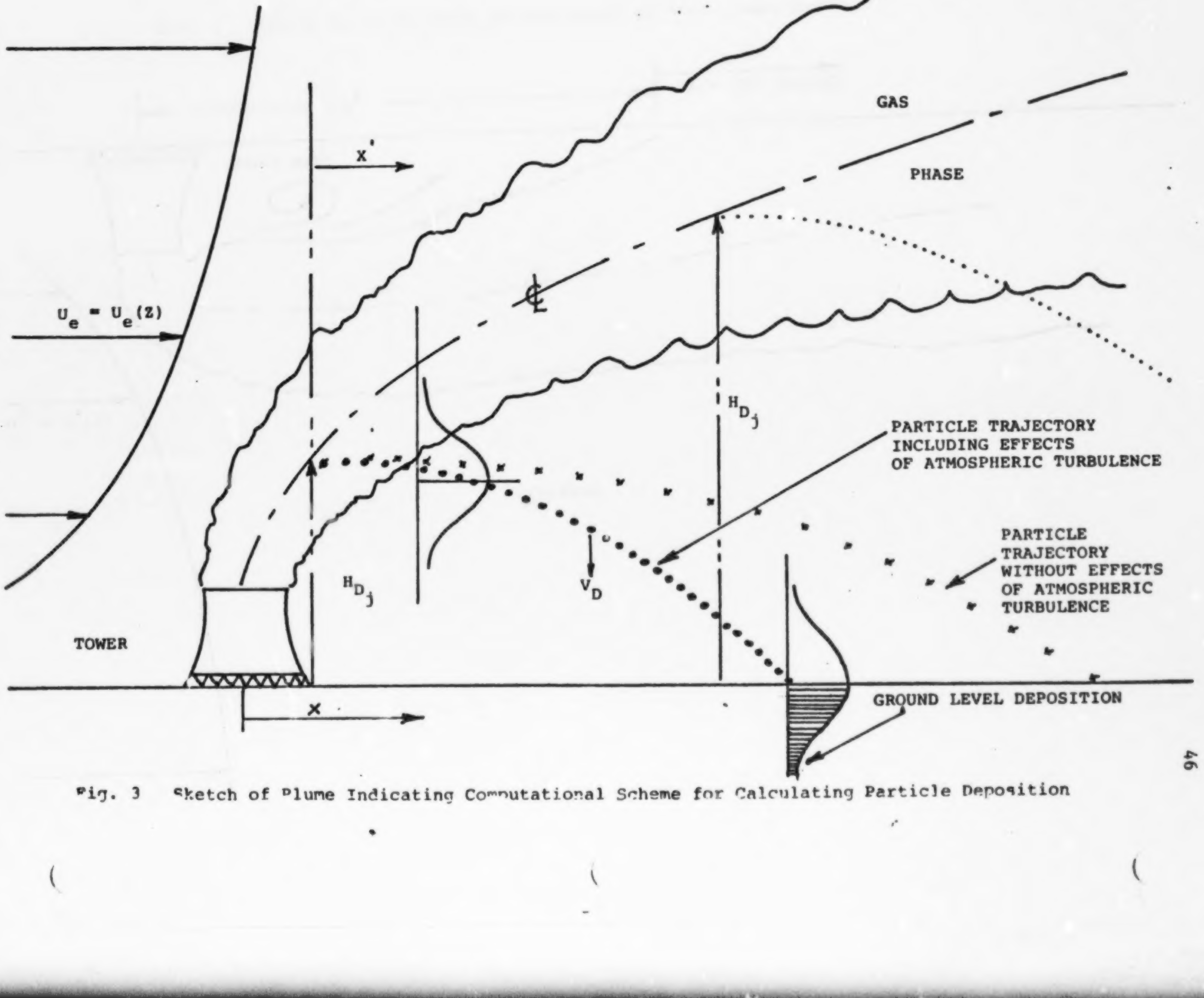

$U_e = U_e(Z)$
X'
GAS
PHASE
℄
H_{D_j}
H_{D_j}
V_D
PARTICLE TRAJECTORY INCLUDING EFFECTS OF ATMOSPHERIC TURBULENCE
PARTICLE TRAJECTORY WITHOUT EFFECTS OF ATMOSPHERIC TURBULENCE
TOWER
X
GROUND LEVEL DEPOSITION

Fig. 3 Sketch of Plume Indicating Computational Scheme for Calculating Particle Deposition

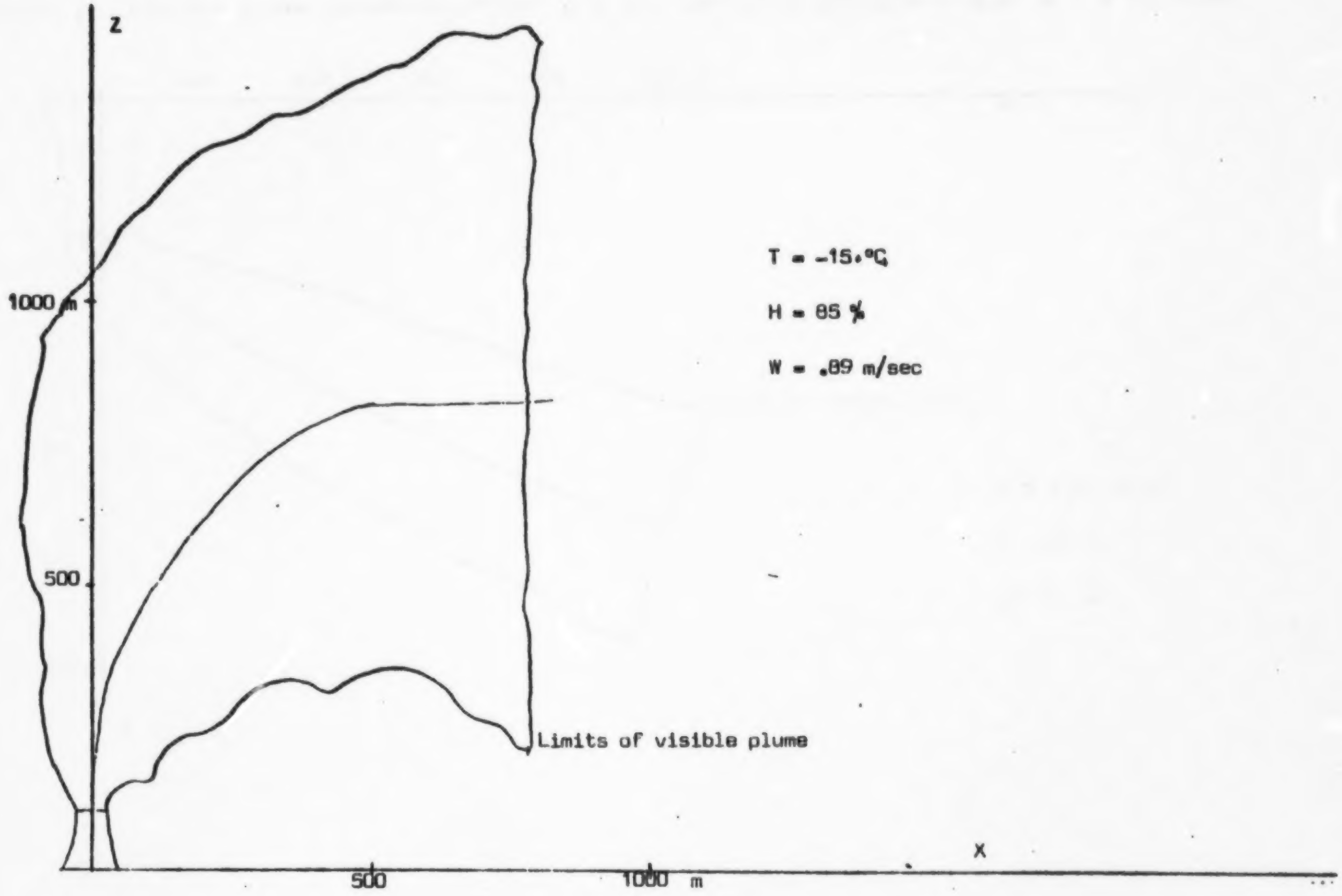


Fig. 4 Visible Plume Characteristics, T = -15°, Relative Humidity = 85%, W = 0.89 m/s

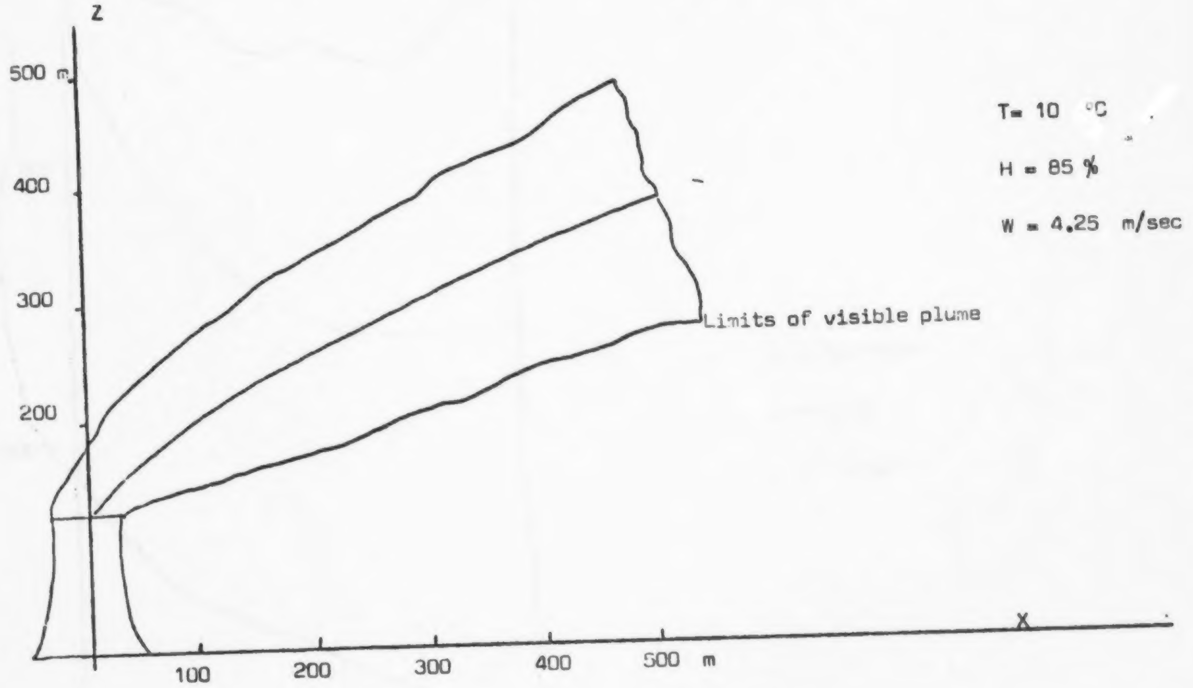


Fig. 5 Visible Plume Characteristics, T = 10°, Relative Humidity = 85%, W = 4.25 m/sec

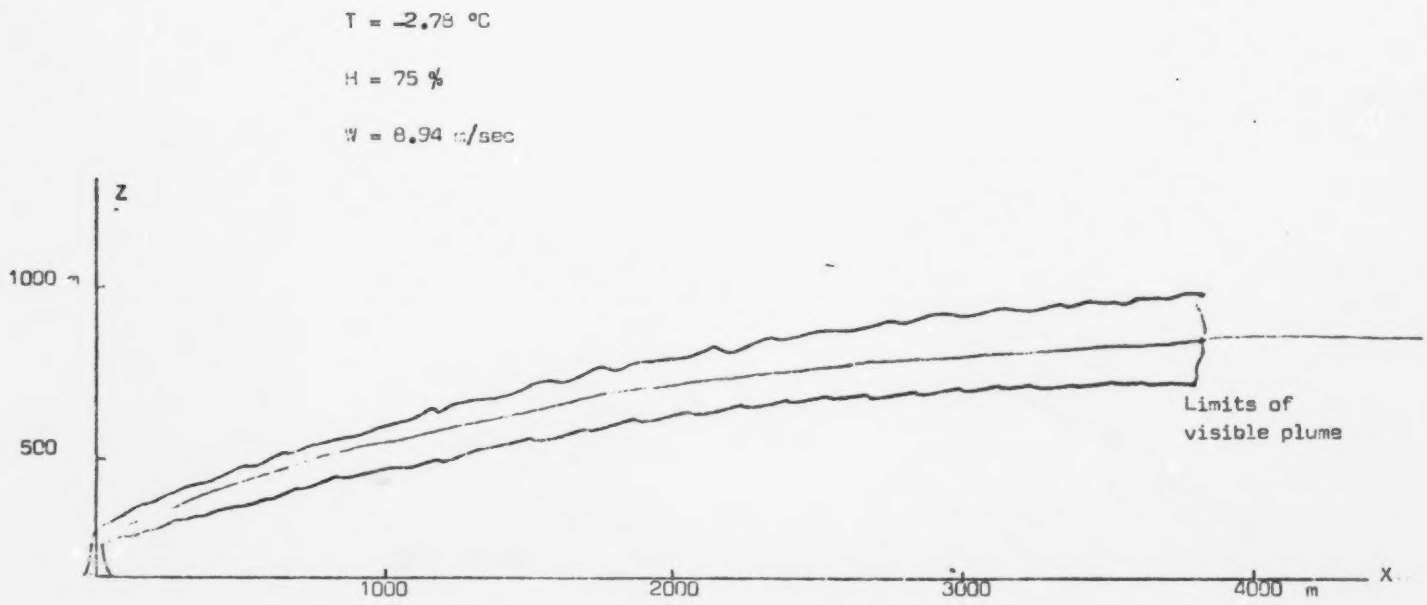


Fig. 6 Visible Plume Characteristics, T = -2.78°C, Relative Humidity = 75%, W = 8.94 m/sec

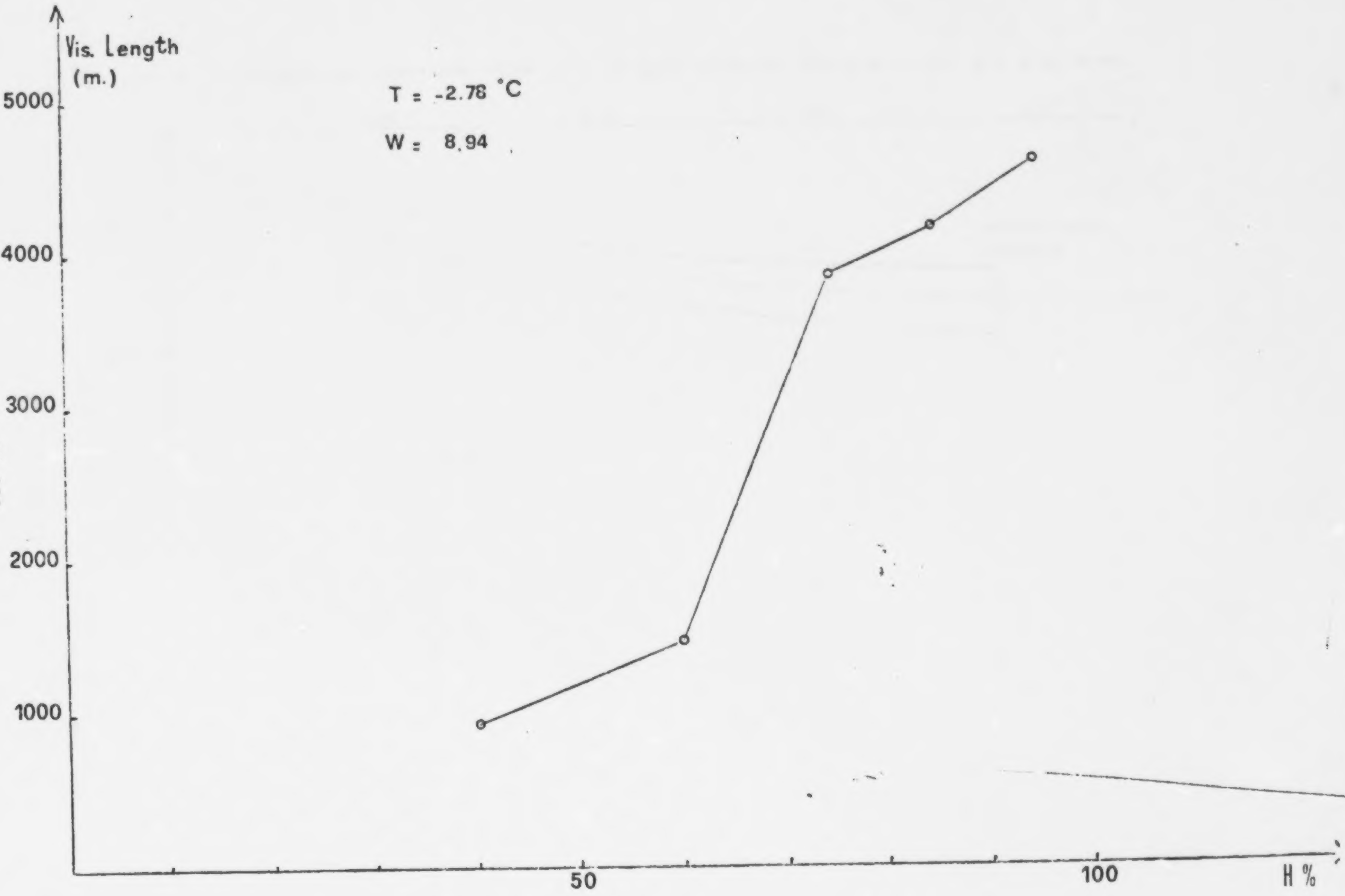


Fig. 7 Visible Plume Length as a Function of Relative Humidity

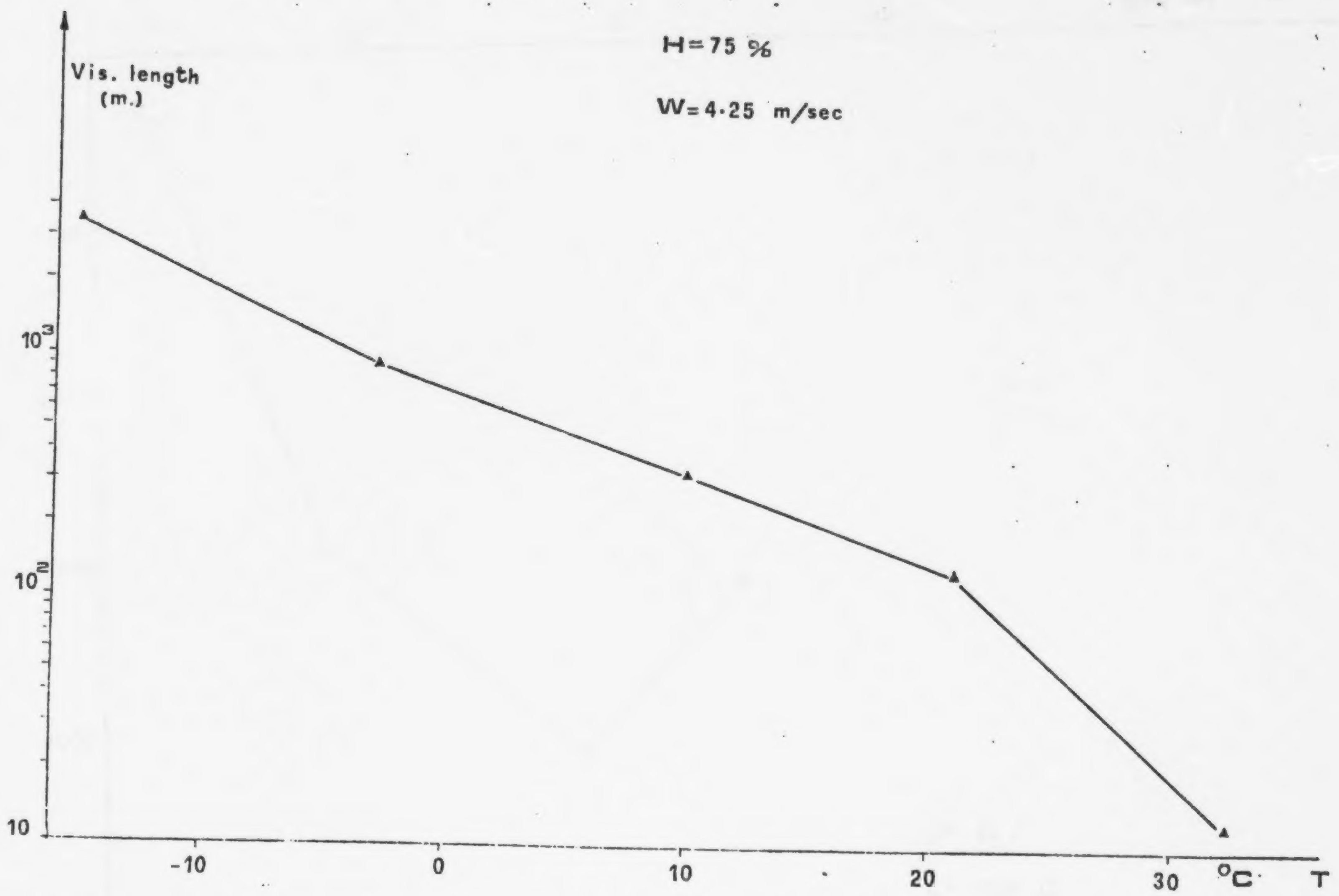


Fig. 8 Visible Plume Length as a Function of Atmospheric Temperature

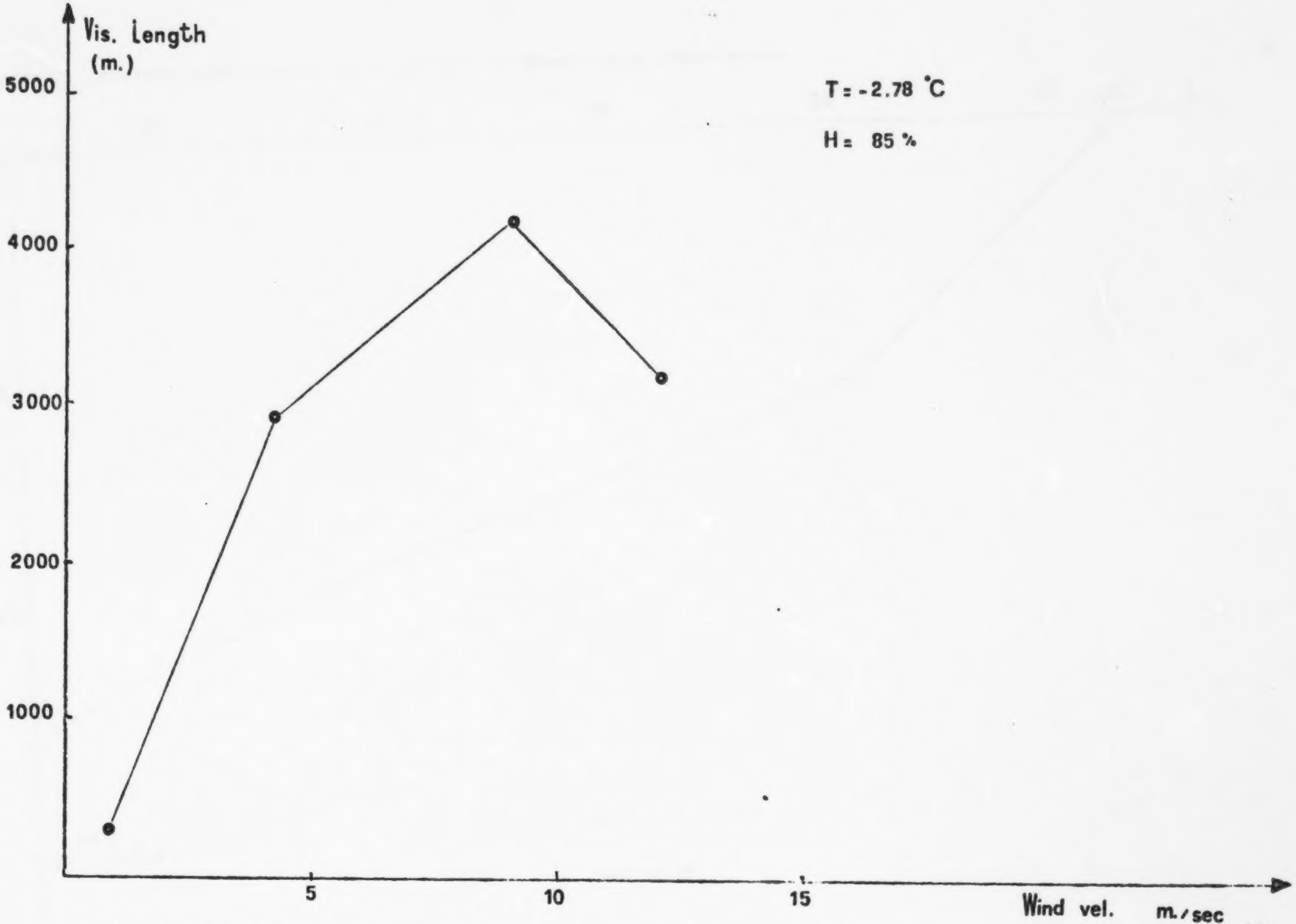
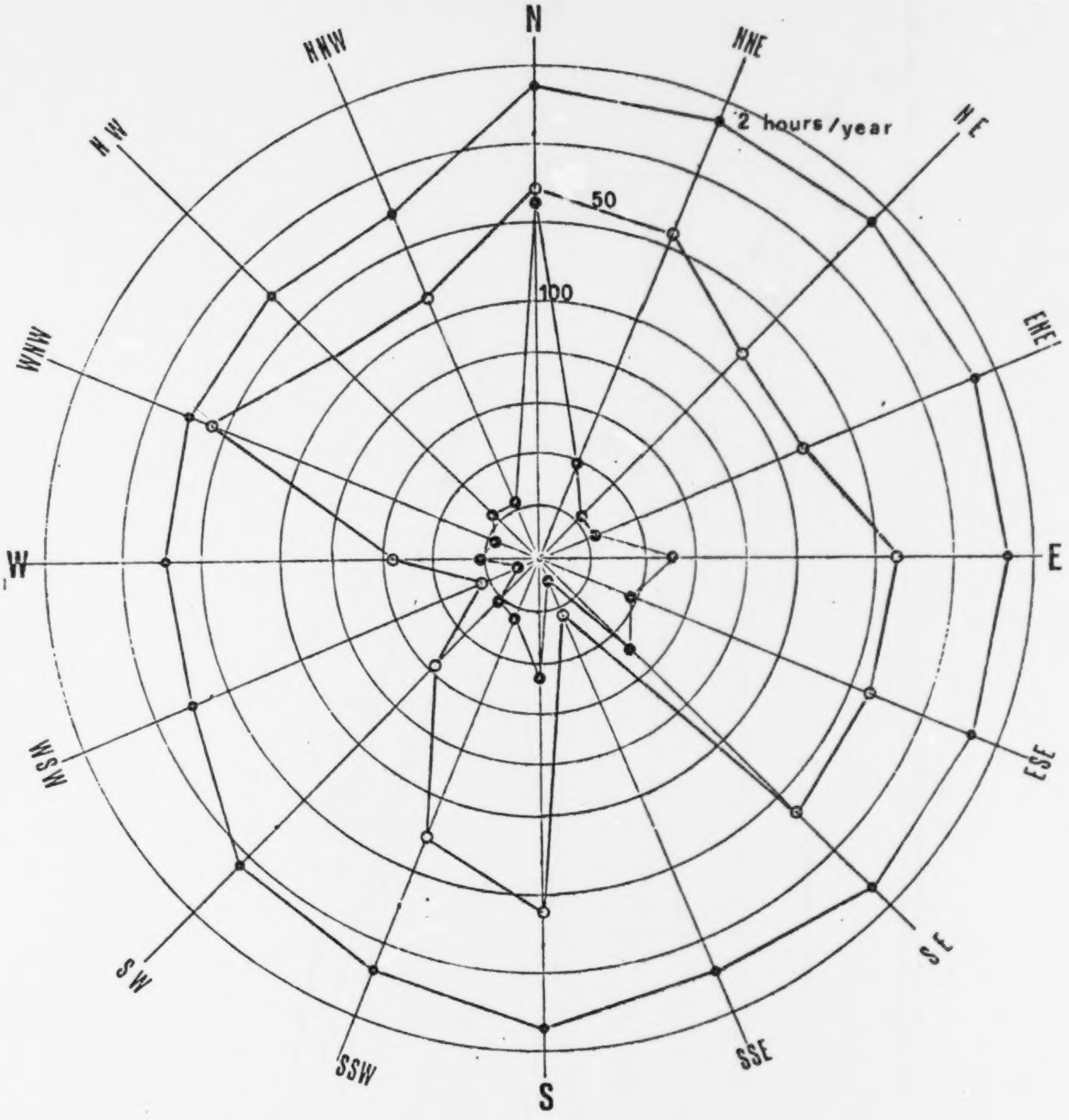


Fig. 9 Visible Plume Length as a Function of Wind Velocity



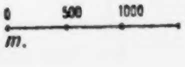


FIG. 10
Annual Average Isopleths of Visible Plume Length

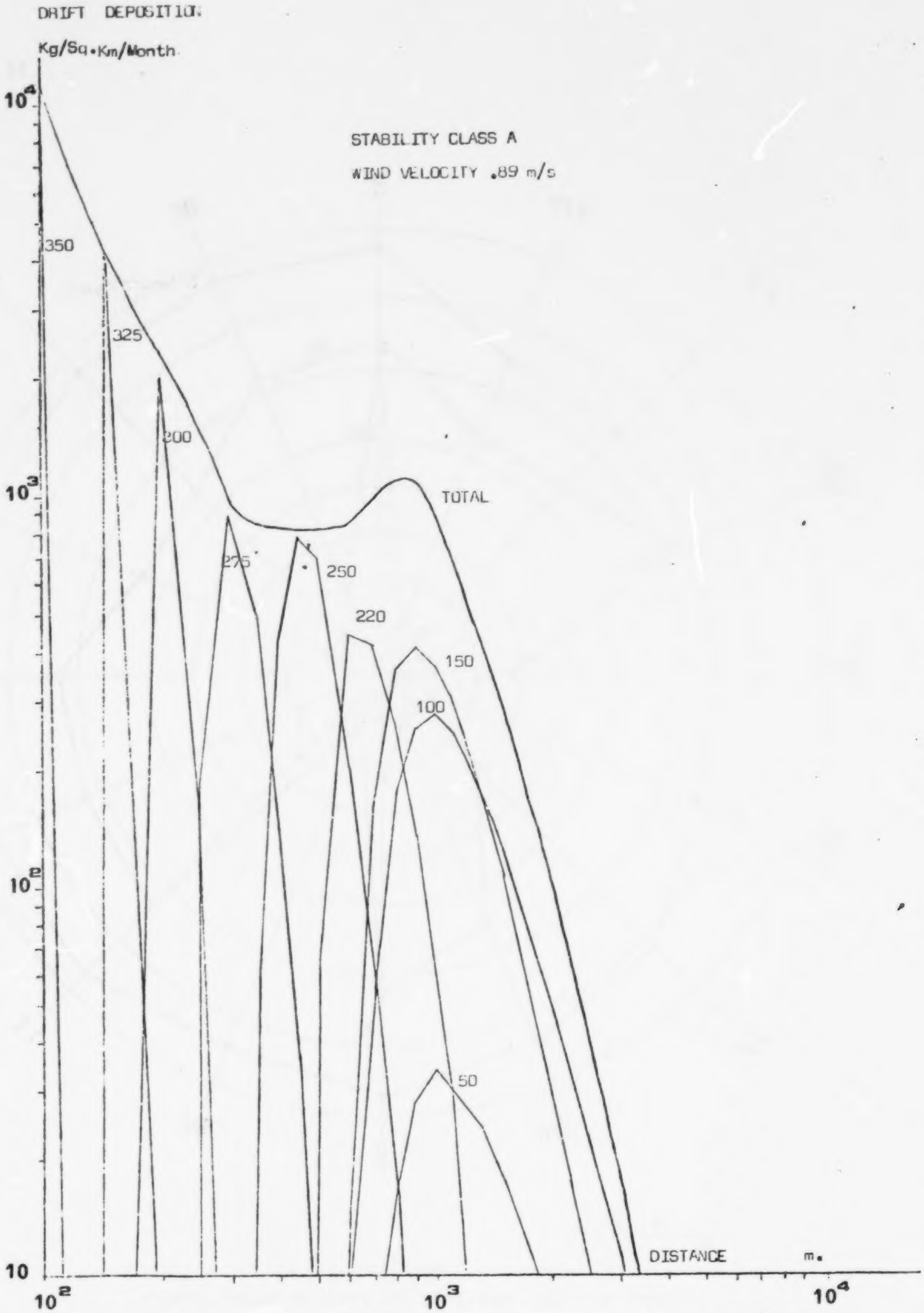


Fig. 11 Distributions of Drift Deposition as a Function of Droplet Diameter Stability A, W = 0.89 m/sec

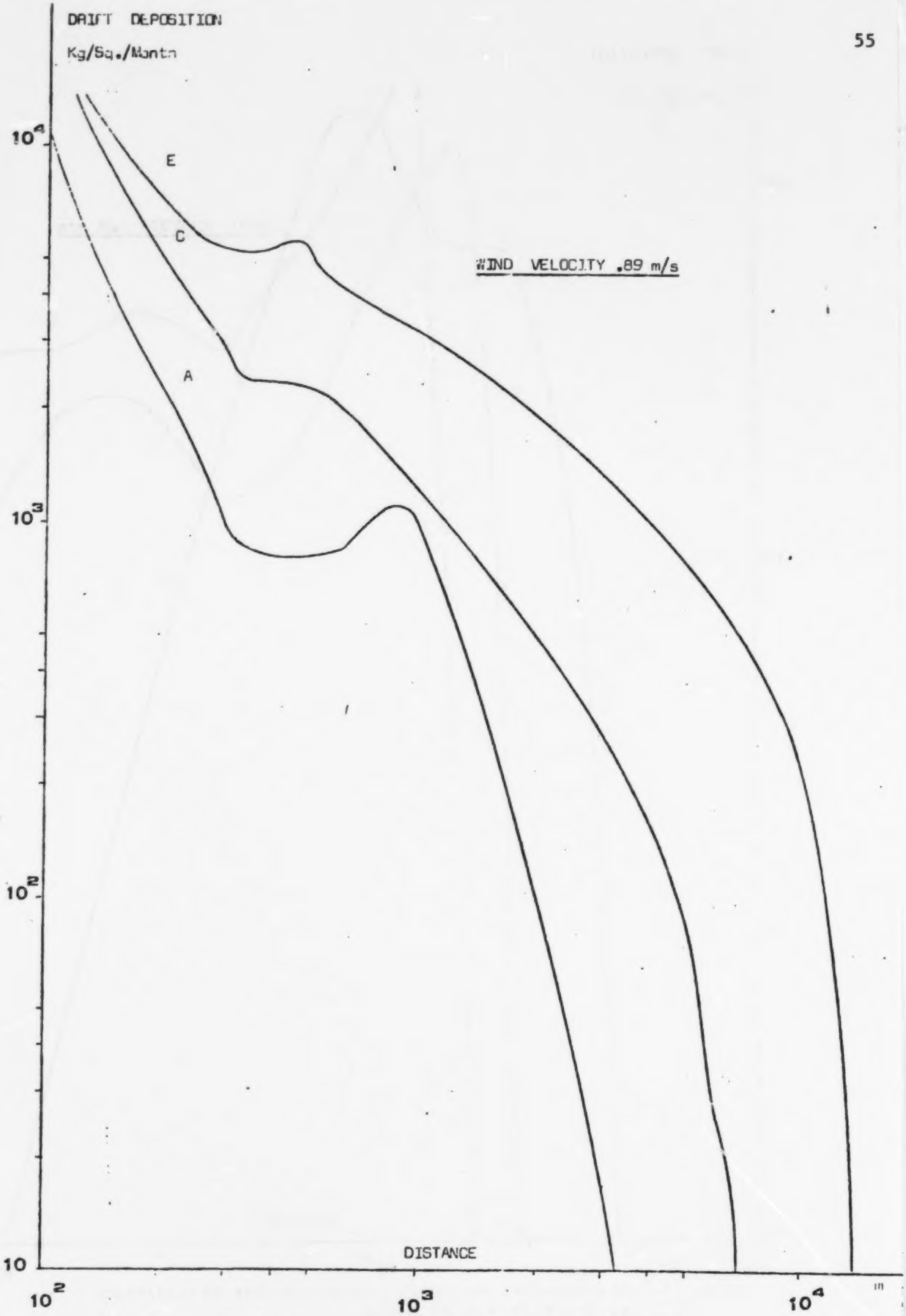


Fig. 12 Distributions of Drift Deposition for Stabilities A, C & E, W = 0.89 m/sec

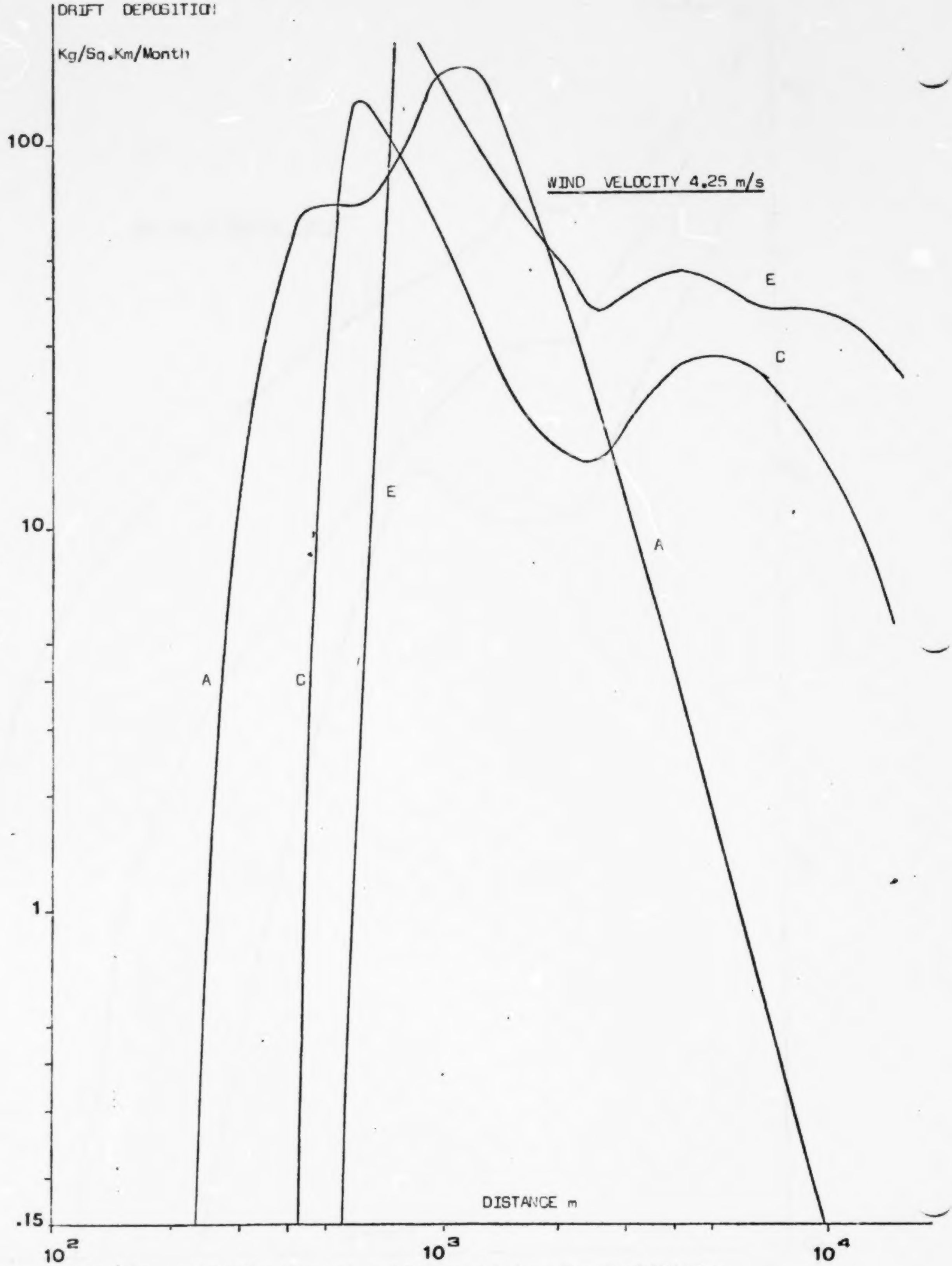


Fig. 13 Distribution of Drift Deposition for Stabilities A, C & E, W = 4.25 m/sec

TA-132

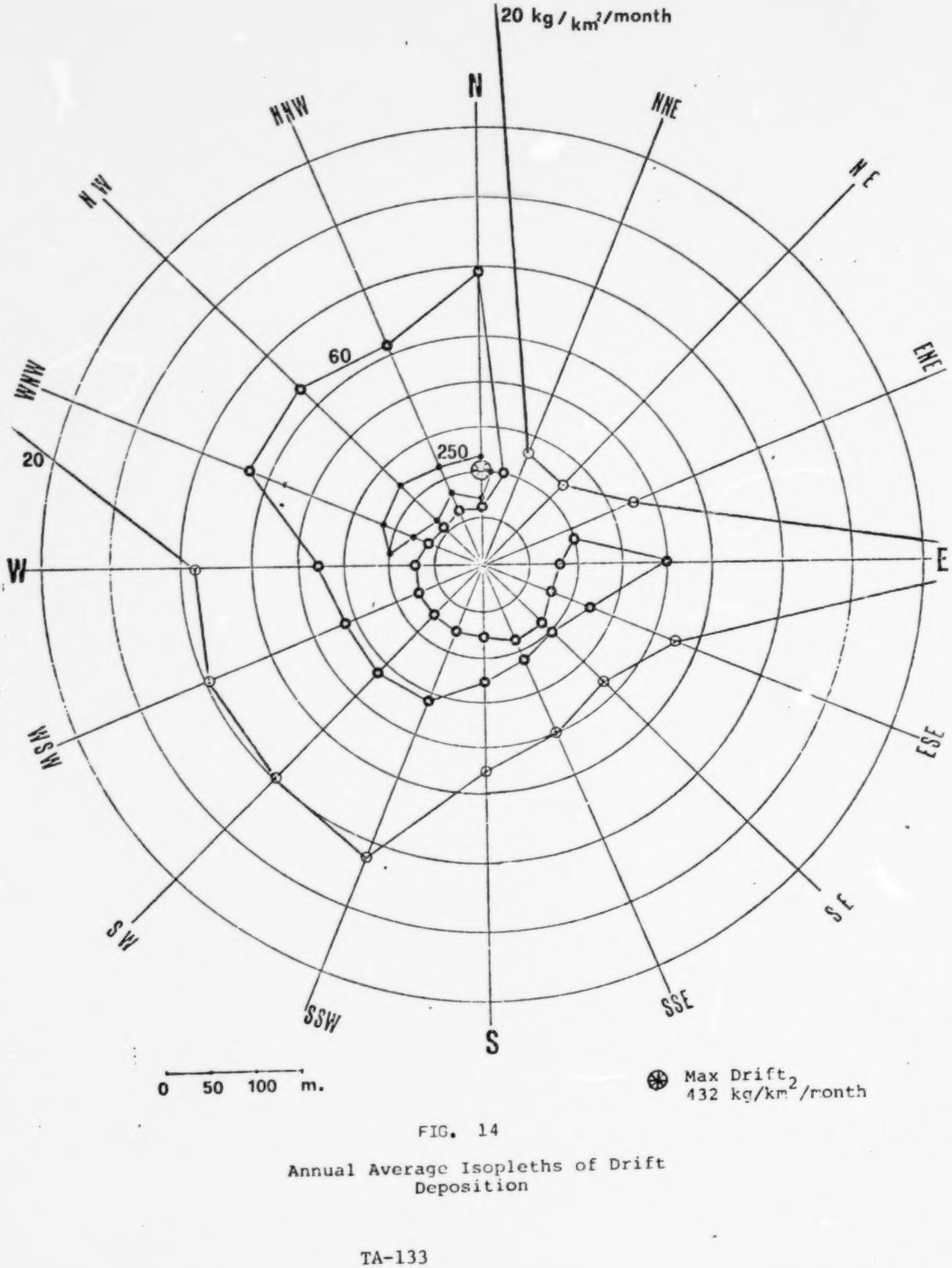


FIG. 14

Annual Average Isopleths of Drift Deposition

TECHNICAL APPENDIX IX

DAMES & MOORE SALT AND LIQUID DRIFT DEPOSITION MODEL DESCRIPTION

General

The mineral deposition and liquid deposition estimates were performed by means of computerized models, which take into account meteorological conditions, source characteristics, and falling droplets dynamics. The following sub-sections describe the methodology and results of these calculations.

Meteorological Input

The preliminary meteorological data input consisted of annual stability wind rose data (STAR output) for Louisville, Kentucky, for the five-year period 1965-1969. Because of (a) the importance of relative humidity in the droplet settling dynamics, and (b) the unavailability of relative humidity wind roses, it was necessary to synthesize the latter by means of climatological data, the STAR output, and theoretical considerations.

Because the estimates were performed to obtain annual deposition rates, an examination of annual mean relative humidity values at Louisville was performed. The mean annual values at 01CST, 07CST, 13CST, and 19CST of 76 percent, 81 percent, 57 percent, and 60 percent respectively were extracted for apportionment of the STAR data. The data were grouped according to stability conditions and were assigned the following relative humidity distribution, by class. It should be emphasized that these solid and liquid drift deposition rates represent annual averages and that seasonal variations of a factor of 2 are likely.

Stability Class	Assigned Relative Humidity	Fraction
A, B, C	70%	.3
	50%	.7
D	70%	.8
	50%	.2
E, F	90%	.3
	70%	.7

By means of a transformation of the STAR output on this basis, equilibrium falling heights, droplet equilibrium conditions (dry crystal or saturated droplet), and settling velocity profiles could be ascertained as necessary.

TA-134, TA-135 and TA-136 are blank.

Tower Source Characteristics

The tower source parameters used as input to the salt and liquid deposition programs are set forth in Table 6.3.1-6. The drift droplet size distributions used for each tower are presented in Table 1 of this Appendix. Salt and liquid deposition estimates were performed for both towers, on the basis of the annual meteorological data.

Modeling Methodology

Plume Rise

The Briggs plume rise equation is used to calculate the ultimate plume heights, where the buoyancy flux parameter F is assumed to be the tower's heat dissipation rate. Because field observations have documented that moist air (cooling tower plumes) rises at the pseudoadiabatic rate, just as dry plumes rise at the adiabatic rate, the Briggs neutral plume rise equation is used for stability A, B, C, D, and E, and the stable plume rise equation is used for F. No augmentation of plume rise for multiple towers or stacks is assumed.

Aerodynamic Downwash

A consideration that is explicitly incorporated into the model is stack- or tower-induced turbulence, i.e., aerodynamic downwash caused by high wind speeds. Downwash is assumed to occur during the two highest speed classes, 9.77 m/sec and 11.82 m/sec. Plume ascent rates are modified at proximal distances, and the vertical eddy diffusivities at these distances are increased.

Droplet Dispersion

The computerized model incorporates the ballistics method for estimating the deposition patterns.

The methodology of the pure ballistics method follows. For each location (meteorological grid point) on the four dimensional stability/wind-speed/wind-direction/relative-humidity matrix, the following is a simplified description of the logic in the computer program. Each droplet size class is treated independently. The effective height of each droplet plume is given by the physical tower height and the plume rise for each wind speed and stability class. The area over which deposition will take place for this droplet class and meteorological grid point is defined by (1) the wind direction, (2) the distance at which the largest droplet in the class (upper class limit) strikes the ground, and (3) the distance at which the smallest droplet (lower class limit) strikes the ground. The amount of the total drift mass which will be deposited on the area thus defined is proportional to the mass fraction in the droplet size class and the relative frequency of occurrence of the meteorological grid point.

The distance at which a given droplet strikes the ground, for a given effective stack height, is a function of (1) droplet size, (2) droplet salinity, (3) wind speed, and (4) relative humidity. Calculations presented in a Pennsylvania State University report (Hosler, 1972) give equilibrium falling height as a function of droplet size, salinity, and relative humidity. On this basis, each droplet's final velocity can be calculated, whether its equilibrium condition is a saturated droplet (RH>76%) or a dry crystal (RH<50%), and the settling velocity profile and settling distance can be obtained from this calculation. The program cycles over the meteorological grid points and the droplet sizes larger than about 130 μm, and accumulates the deposition rates calculated at distances of interest.

In order to account for the variable settling velocity of the droplets, a procedure similar to that used in the ballistics method is employed. From this basis, the vertical velocity profile of each droplet is obtained. This permits calculation of the plume position and settling velocity at each distance.

When the ground-level concentration has been calculated, then the deposition rate at the surface is given by the sum of the vertical advective mass flux and the vertical eddy mass flux:

$$D_r = W_s \chi (X, Y, 0) - k_z \frac{\delta x}{\delta z}$$

Where:

D_r = surface deposition rate (grams/meter^2/second)

W_s = settling velocity (meters/second)

χ = ground-level concentration (grams/meter^3)

k_z = vertical eddy diffusivity (meter^2/second)

The second term ($- k_z \frac{\delta x}{\delta z}$) in the equation is very small compared to the first term, and it is not used in the computer calculations.

The continuous distribution of droplet sizes less than about 130 μm is regarded to be adequately represented by five discrete drop sizes, at which the entire mass of each droplet class is assumed to be concentrated. Each droplet size is treated as a separate plume of known source strength. Coagulation effectives among the drift droplets and with the condensing vapor plume are not quantitatively incorporated into the model, although the approximations necessary in the drop settling dynamics imply effective velocity adjustments in accordance with those which would have been calculated had coagulation been directly considered.

The program accumulates deposition rates as a function of distance and direction for each droplet class taken with each meteorological grid point. The output is in the form of mass deposition per unit area per unit time over a specified distance/direction matrix around the source.

Several uncertainties may affect the accuracy of the deposition estimates, because rigorous field measurements to calibrate mineral deposition models are not yet available. These uncertainties include the unknown effects of droplet coagulation or merging with the vapor plume, the unknown relationship between vapor plume rise and droplet plume rise, and the unknown diffusivity of droplets, as opposed to gases.

TECHNICAL APPENDIX IX

Table 1

DRIFT DROPLET SIZE DISTRIBUTION

Droplet Class Midpoint (radius in μm)	Mass Fraction
25	.22
50	.42
75	.18
100	.08
125	.035
150	.020
175	.015
200	.010
225	.007
250	.006
275	.004
300	.003

LOUISVILLE GAS AND ELECTRIC COMPANY

TRIMBLE COUNTY GENERATING STATION

PROJECT 31-7296-101

COOLING TOWER BLOWDOWN DISPERSION STUDY

January 9, 1978

FLUOR PIONEER INC.

CHICAGO, ILLINOIS 60606

COOLING TOWER BLOWDOWN DISPERSION STUDY

TABLE OF CONTENTS

I. Purpose and Scope

II. Conclusions and Recommendations

III. Basis of Study

IV. Model Selection and Analysis

V. Ambient Data
  a. Ohio River
  b. Atmosphere

VI. Cooling Tower Chlorination Analysis

VII. Selection of Discharge Structure

VIII. Computer Analysis and Results

IX. Environmental Effects of Discharge

References

I PURPOSE AND SCOPE

A. Purpose

The purpose of this study is to demonstrate that the cooling tower blowdown discharged into the Ohio River will produce an environmentally acceptable size mixing zone under worst expected combination of river-air ambient condition and power plant operating mode. The total residual chlorine concentration outside this mixing zone will not exceed 0.01 mg/l, while the river water temperatures will not exceed the limits imposed by regulatory agencies (EPA, State of Kentucky, ORSANCO).

B. Scope

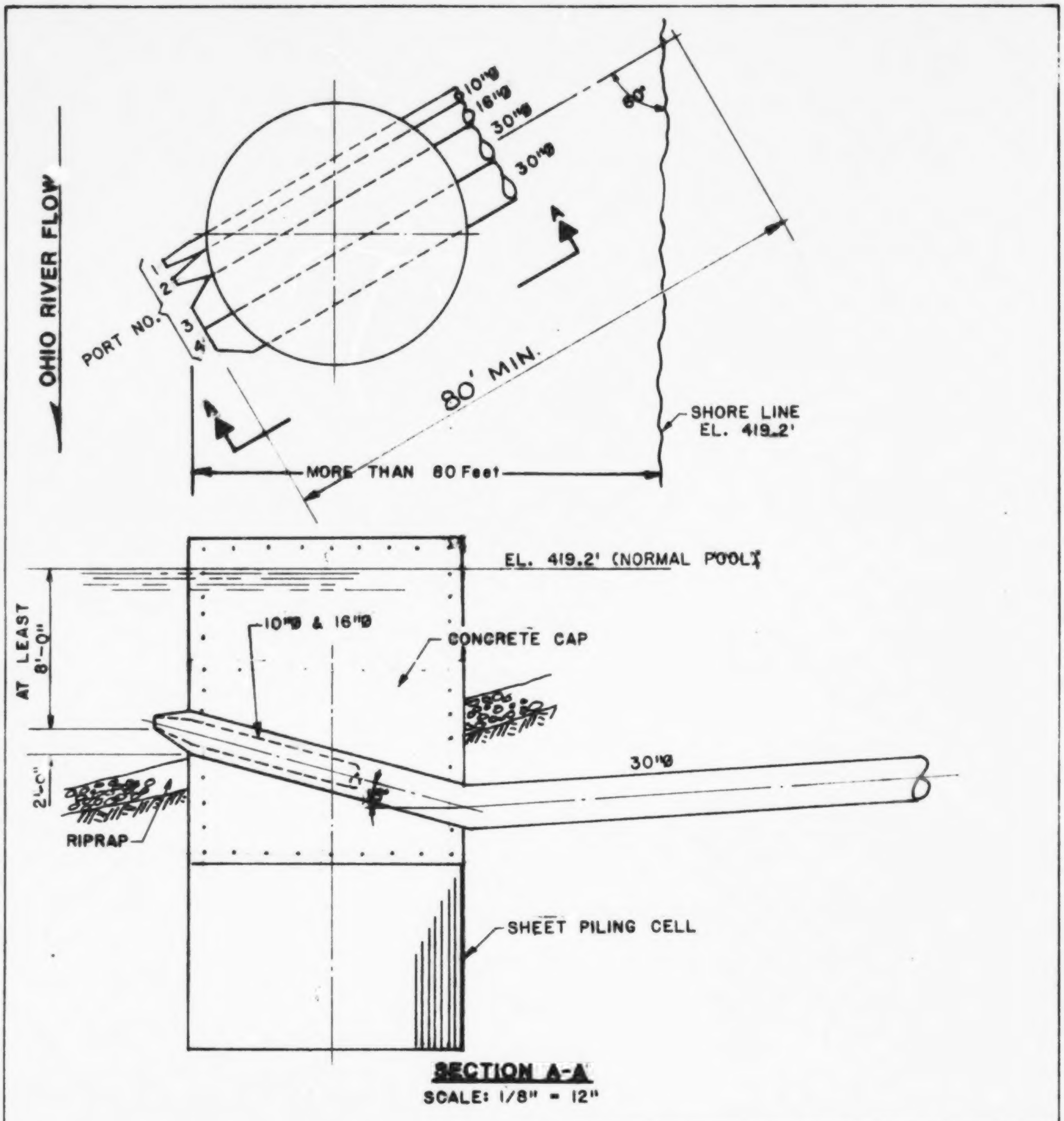
To satisfy the purpose of this report, the following work has been performed and the results are presented as an integral part of this study:

1. Development and listing of criteria governing the design of the cooling tower blowdown system.
2. Selection of a credible mathematical computer model to predict the size of mixing zone.
3. Preparation of Ohio River data, such as flow rates, velocities, temperatures and variation of same during winter, spring, summer and autumn seasons.
4. Development of chlorination schemes designed to minimize concentration of chlorine in the cooling tower blowdown.
5. Selection of a discharge structure designed to minimize all adverse effects on environment while assuring satisfactory plant operation.
6. Computer analysis of cooling tower blowdown dispersion and graphical presentation of computer generated size of mixing zones for various ambient and plant operating conditions.
7. Based on results of this study, the suggested size of mixing zone for cooling tower blowdown has been determined.

II CONCLUSIONS AND RECOMMENDATIONS

Based on the results presented in this study, it is concluded that a subsurface, multipipe, gravity type discharge structure shown on Figure 2-1 will produce least impact on the environment, while satisfying power plant operating requirements. The cooling tower blowdown discharged through the recommended structure into the Ohio River will achieve satisfactory mixing in a small zone within 140 ft. of the discharge. This mixing zone is based on a computer generated plume centerline length of 70 ft. and the computer model validity factor of 2.

It is suggested that in the NPDES permit the EPA assign a mixing zone of 140 ft., measured in any direction from the discharge structure.


OHIO RIVER FLOW
PORT NO.
1
2
3
4
10"Ø
16"Ø
30"Ø
30"Ø
60°
A
A
80' MIN.
SHORE LINE
EL. 419.2'
MORE THAN 80 Feet
EL. 419.2' (NORMAL POOL)
AT LEAST 8'-0"
10"Ø & 16"Ø
CONCRETE CAP
30"Ø
2'-0"
RIPRAP
SHEET PILING CELL
SECTION A-A
SCALE: 1/8" = 12"

PORT NO.	PORT DIMENSIONS	DISCHARGE G.P.M.	VELOCITY F.P.S.
1	.25 ft. x .50 ft.	0-1000	0-17.74
2	.45 ft. x .94 ft.	1000-5000	5.04-25.23
3	1.08 ft. x 2.16 ft.	5000-21000	4.79-20.15
3&4	2-1.08 ft. x 2.16 ft.	21000-42000	10.07-20.14

FIGURE 2-1 CONCEPTUAL DESIGN OF PREFERRED DISCHARGE STRUCTURE

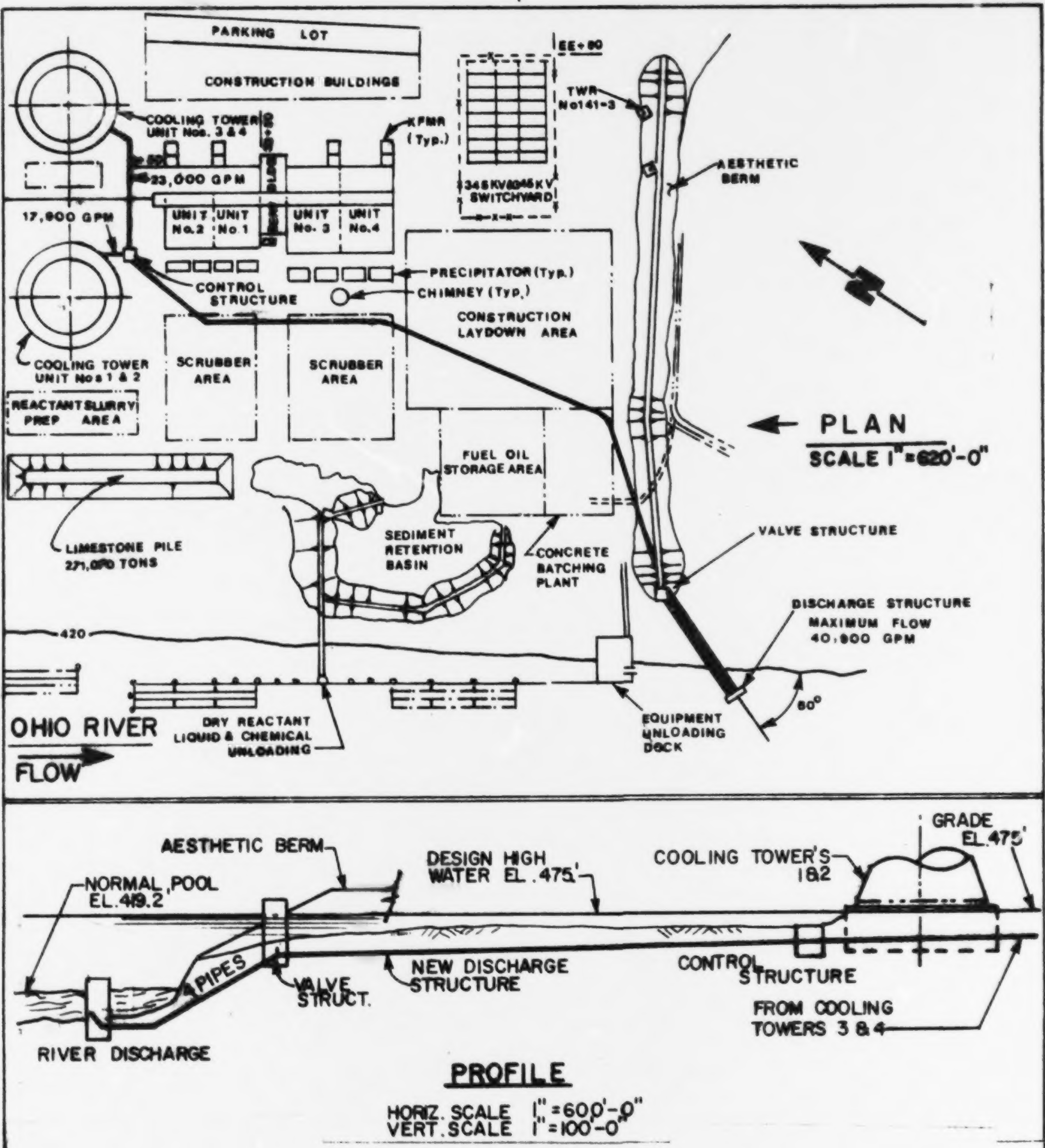

PARKING LOT
CONSTRUCTION BUILDINGS
EE+80
COOLING TOWER UNIT Nos. 3 & 4
KFMR (Typ.)
TWR No141-3
23,000 GPM
17,900 GPM
UNIT No.2
UNIT No.1
UNIT No. 3
UNIT No.4
345KV&345KV SWITCHYARD
AESTHETIC BERM
CONTROL STRUCTURE
PRECIPITATOR (Typ.)
CHIMNEY (Typ.)
CONSTRUCTION LAYDOWN AREA
N
COOLING TOWER UNIT Nos 1 & 2
SCRUBBER AREA
SCRUBBER AREA
REACTANT SLURRY PREP AREA
PLAN
SCALE 1" =620'-0"
FUEL OIL STORAGE AREA
LIMESTONE PILE 271,070 TONS
SEDIMENT RETENTION BASIN
CONCRETE BATCHING PLANT
VALVE STRUCTURE
DISCHARGE STRUCTURE MAXIMUM FLOW 40,900 GPM
420
OHIO RIVER
FLOW
DRY REACTANT LIQUID & CHEMICAL UNLOADING
EQUIPMENT UNLOADING DOCK
60°
AESTHETIC BERM
DESIGN HIGH WATER EL. 475'
COOLING TOWER'S 1&2
GRADE EL.475'
NORMAL POOL EL. 419.2'
4 PIPES
VALVE STRUCT.
NEW DISCHARGE STRUCTURE
CONTROL STRUCTURE
FROM COOLING TOWERS 3 & 4
RIVER DISCHARGE
PROFILE
HORIZ. SCALE 1" =600'-0"
VERT. SCALE 1" =100'-0"

FIGURE 2-2 SITE ARRANGEMENT FOR DISCHARGE STRUCTURE

III BASIS OF STUDY

1. Water Temperature

Outside the mixing zone, the river water cannot exceed:

a. Maximum temperature change of 5°F

b. Maximum temperatures by month, as follows:

Jan.	50°F	July	89°F
Feb.	50°F	August	89°F
Mar.	60°F	Sept.	87°F
Apr.	70°F	Oct.	78°F
May	80°F	Nov.	70°F
June	87°F	Dec.	57°F

Above requirements are governed by:

ORSANCO Pollution Control Standard No. 2-70

Kentucky Water Quality Standards 401 KAR 5:025

2. Concentration of Chlorine

Outside the mixing zone the cooling tower blowdown cannot contain chlorine in concentrations exceeding one tenth of the 96 hour total lethal dose for species of aquatic biota existing in the river.

Above is the requirement of the Kentucky Water Quality Standards 401 KAR 5:025. This Kentucky requirement has been quantified as follows:

At the boundary of the mixing zone the concentration of chlorine cannot exceed 0.01 mg/1.

3. The discharge structure must promote rapid mixing to achieve smallest possible mixing zone, thereby minimizing adverse impact on river biota.

4. The discharge structure is to be located in an area of low environmental value to avoid damage to river biota. Furthermore, to minimize adverse impact on bentic organisms, the point of discharge is to be above the river bottom, pointed at an angle above the horizontal plane.

5. To avoid recirculation, the discharge and intake structures must be located a substantial distance apart.

6. The design of the discharge structure must consider reliability and ease of maintenance. These features provide consistency of operation and limit adverse environmental impact resulting from malfunction of the structure.

7. The discharge structure will be designed to operate between 20 fps to 2 fps velocity, to limit deterioration of the pipe and prevent siltation.

8. The installed cost/benefit of the discharge structure has to be economically justifiable with respect to alternate designs.

9. Normal operation of the cooling towers during chlorination will be at five cycles of concentration for the cooling towers.

IV MODEL SELECTION AND ANALYSIS

The selection process that took place in choosing a model was executed in two phases. The first phase was an elimination process reviewing all of the models available. The criteria examined for this phase included model assumptions and general fit to the study; ease of execution, validated or not; and general methodology of the model. Some of the models examined and discarded during this phase included LODIPS, TETRAD, DITMARS, STREAM, CFSTR, COLHEAT and EDINGER-GEYER models.

The second phase of the analysis was performed on the models remaining after the initial elimination phase. A brief description of these models follow:

A. Computer Simulation Models

1. Motz and Benedict (2, 3, 4, 5) (Vanderbilt University)

   Type of Model: Two-dimensional (horizontal) integral, steady state

2. Shirazi and Davis (6, 7) (Pacific Northwest Environmental Research Laboratory)

   Type of Model: Three-dimensional integral, steady state

3. Pritchard (Model No.1) (8, 9) (Chesapeake Bay Institute, Johns Hopkins University)

   Type of Model: Quasi three-dimensional, integral/phenomenological, steady state

4. Brady and Geyer (10) (The Johns Hopkins University)

   Type of Model: Three-dimensional numerical, transient

5. Paul & Lick (11) (Case Western Reserve University)

   Type of Model: Three-Dimensional transient numerical model

B. Rationale for Selecting the Sharazi-Davis Model (PDS)

The rationale for selecting the PDS Model includes:

1. It is state of the art.
2. It was developed by the U.S. EPA.
3. It has been validated utilizing an operating power plant (Point Beach Plant Unit 1) within a factor of 2 in isotherm length and width, and a factor of 5 in surface areas. (12)
4. Its acceptance as being one of the most accurate models available. (12)
5. Its general ease of utilization.

6. Its overall fit to the conditions of the study.

7. Its use by Argonne National Laboratory in their thermal plume studies.

C. Assumptions for the PDS Model

1. The thermal plume characteristics are not affected by the river bottom as long as depth of river exceeds predicted depth of plume.

2. The river current is uniform and constant throughout the area affected by the plume, and wind has no effect on the river velocity.

3. The discharge velocity, temperature, and volume are constant and uniform at the end of the discharge pipe.

D. Sensitivity Analysis of the PDS Model

The purpose of the sensitivity analysis was to methodically investigate the variables that affect the computer simulation program. This effort included investigation of the sensitivities and interactions of these different variables. This information was then utilized in designing a discharge structure that would produce the shortest centerline distance of the effluent plume under average and extreme plant operating conditions.

The two factors that were studied and specifically considered during this phase of the study were temperature and chlorine concentration. The intent of the study was to achieve: 1) a minimal area for the 5°F excess temperature isotherm; and 2) a minimal plume centerline length as measured from the discharge structure to a point where the discharged blowdown water (and hence the chlorine concentration) reaches a point of 20:1 mixing with the ambient river water as measured by the excess velocity distribution within the plume boundaries.

The variables investigated during the study were: 1) Froude number; 2) angle of discharge; 3) surface heat exchange coefficient; 4) aspect ratio; and 5) velocity ratio.

The results of the PDS sensitivity study and a discussion of the method is summarized in Appendix A. (On file at EPA Region IV office.)

V AMBIENT DATA

a. Ohio River

The average seasonal flow was calculated by averaging monthly average flows at McAlpine Dam in Louisville for three months for a 16-year period of record. (The summer season, for example, includes June, July, and August.) Flow at Louisville is a reasonable approximation of flow at the site, since there is no major stream entering the Ohio River between McAlpine Dam and the site. Data was taken from the U.S. Geological Survey publications "Water Resources Data for Kentucky" for Water Years 1948-49 through 1956-57, and 1961-62 through 1967-68.

The 10 percentile low seasonal flow was determined by ranking the 92 average daily flows in summer and the 90 or 91 average daily flows in winter, selecting the ninth lowest flow, and averaging these flows for the above 16-year period.

The seven-day, 10-year low flow is an estimate provided by the Corps of Engineers, based on flows augmented by a system of upstream reservoirs that existed or were planned in 1968. It is now anticipated that some of these reservoirs will not be constructed. A revised estimate of the seven-day, 10-year low flow is not available at this time.

River stages at the plant site for various flows were estimated by evaluating stage-flow relationships at McAlpine Dam at Louisville and at a guage formerly located at Madison, Indiana, and determining the required stages by interpolation.

Average river velocities were calculated by dividing flow rates by the cross-sectional areas of the river at the stages corresponding to those flow rates.

River velocities at the nozzle were calculated by applying the following relationship (refer to "Open Channel Hydraulics," V.T. Chow, p. 202):

$$Vn = 5.75\ Vf \log 30\ (1-dn/Y)\ y/k$$

where $V_f = gRs$

Y = river depth at nozzle

dn = depth at nozzle

k = 0.66

R = hydraulic radius

S = hydraulic gradient

The resulting velocity was reduced 25 percent because of the lower velocities that occur on the Kentucky side of the river at this point.

Average temperatures were calculated from the average monthly temperatures obtained from ORSANCO for the years 1970 through 1974.

The temperatures used with the low flow rates were the minimum monthly temperatures recorded in a season for the above years.

A survey of selected years indicated that the lowest flows occurred most frequently in the month of August, and this month was used for the seven-day, 10-year low flow simulation.

b. Atmosphere

Atmospheric conditions of wet bulb temperature, dry bulb temperature, and relative humidity are significant with respect to determining blowdown rate from the tower since they effect tower performance, hot water temperature, cold water temperature and evaporation rate. Blowdown rates were calculated using the following formula:

$$B = \frac{Ev}{C-1} - (D + L)$$

where: B = Blowdown rate
Ev = Rate of evaporation from tower
C = Tower cycles of concentration
D = Tower drift loss
L = Miscellaneous losses

Drift plus miscellaneous losses (D + L) were realistically taken to be a total of three hundreths of a percent (.03%) of the circulating water flow rate. Evaporative losses (Ev) were estimated using the methodology defined in the article "Estimating Cooling Tower Evaporation Rates" by T. H. Hamilton, in the March 1977 edition of Power Engineering.

Wet bulb and relative humidity data was taken from National Weather Service data records of monthly reports entitled "Local Climatological Data" issued by the U.S. Department of Commerce, Environmental Science Services Administration, Environmental Data Service recorded at Standiford Field Station, Louisville, Kentucky. Data available covered a period from October 1969 through February 1973, or roughly three years. Seasonal graphs were prepared for maximum, average, and minimum values of wet bulb and relative humidity vs. time of day. These graphs and seasonal load duration graphs for weekday load cycles were used to determine the average value of wet bulb and relative humidity for the daily time period coincident with the weekday load peak. Dry bulb temperatures were taken from a standard psychrometric chart by application of these average wet bulb and relative humidity values.

VI COOLING TOWER CHLORINATION ANALYSIS

A study was conducted to estimate the total residual chlorine concentration that could be present in the cooling tower blowdown of Trimble County Station. Two different schemes of chlorination were examined and are discussed in detail in the following paragraphs.

Certain assumptions were made to simplify the calculation required and to include factors influencing the chlorination process in real life. These assumptions are as listed below.

1. The total residual chlorine concentration at cooling condenser's outlet is maintained at 0.5 mg/l during the chlorination process to assure effective controlling of microbial fouling.

2. Chlorination of the station's four cooling units is performed during the course of one working shift.

3. Chlorination time of one hour on each cooling unit is sufficient to control microbial fouling of cooling condensers.

4. Blowdown from cooling towers will be inhibited for two to three hours after one hour of chlorination is completed, depending on the chlorination scheme implemented.

5. Blowdown from each cooling unit during different cycles of operation is tabulated below, and expressed in gallons per minute (GPM).

Unit	Cycle of Concentration			
	2	3	4	5
1	4,610	2,271	1,481	1,090
2	4,610	2,271	1,481	1,090
3	6,272	3,071	2,015	1,483
4	6,272	3,071	2,015	1,483
Possible Maximum Blowdown	21,764	10,684	6,992	5,146

6. When blowdown from chlorinated unit(s) is mixed with the recycled cooling water or blowdown from the rest of the unchlorinated units, the two effluents are completely mixed, and the final total residual chlorine concentration is decreased in proportion to the final volume.

7. Chlorine decay rates used to calculate the final residual chlorine in blowdown are illustrated in Figure 6.3 . In the interest of conservatism, the decay rates that yield the highest residual chlorine concentration were used.

8. The change in chlorine decay rates due to the change of prevailing weather conditions was not considered.

Chlorination Schemes:

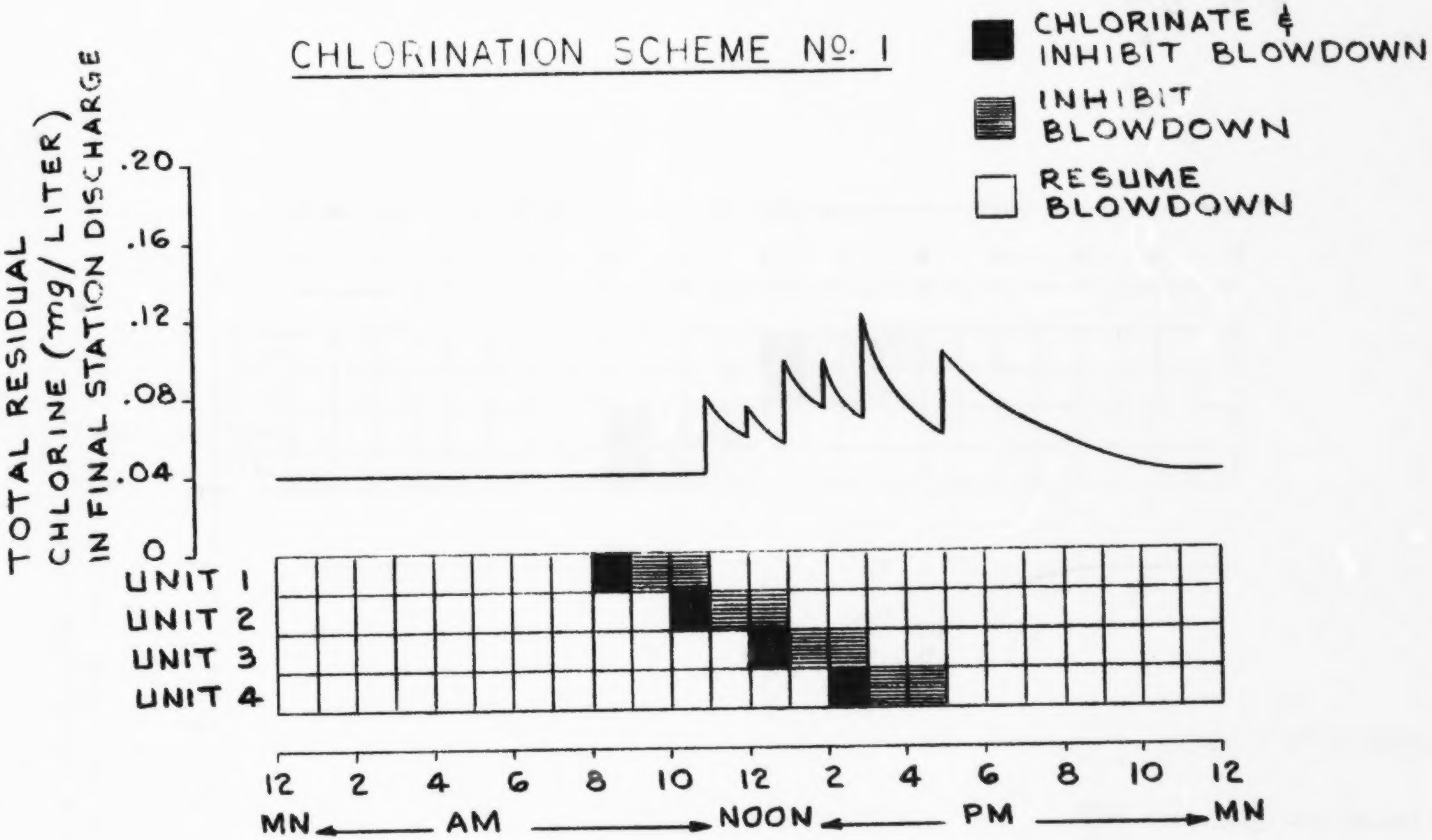
For the purpose of this study, two chlorination schemes were examined, and the final concentration of total residual chlorine was calculated and plotted against time, as shown in Figures 6-1 and 6.2. The two schemes represent two different ways of chlorinating the four condenser units.

The first scheme represents chlorination of each condenser unit separately. During chlorine injection, process blowdown is stopped and continues inhibited for two hours after the chlorination is completed, as illustrated in Figure 6-1.

The second scheme considers chlorinating Units 1 and 2 at the same time for one hour, while blowdown from these units is inhibited for three hours (one hour in which chlorination is performed and two hours after chlorination is completed). Chlorination on Units 3 and 4 is then performed in the same fashion. The second chlorination scheme and the final total residual chlorine concentration in the station blowdown is illustrated in Figure 6-2.

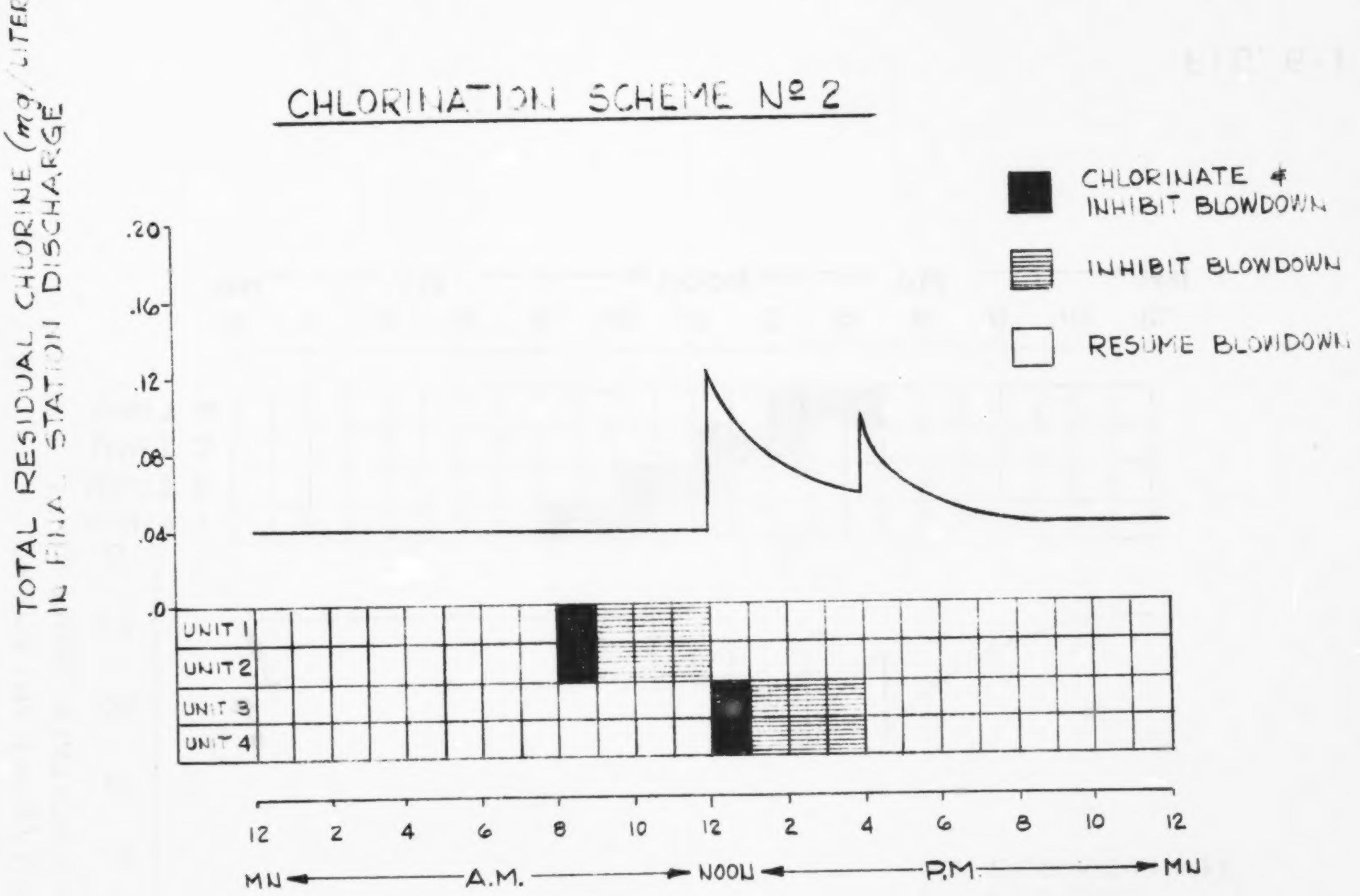
Results:

Figures 6-1 and 6-2 indicate that the total residual chlorine concentration associated with each blowdown can be anywhere from 0.04 mg/l to .12 mg/l, depending on the time passed after chlorination and the chlorination scheme used. While the above two schemes represent the total residual chlorine concentration that is most likely to occur in the station blowdown, the total residual chlorine concentration may reach .2 mg/l when only one condenser unit is in operation and there is no mixing effect from the other three condenser units, assuming that blowdown is inhibited for two hours after chlorination is completed.



CHLORINATION SCHEME No. 1

FIG. 6-1



CHLORINATION SCHEME № 2

FIG. 6-2

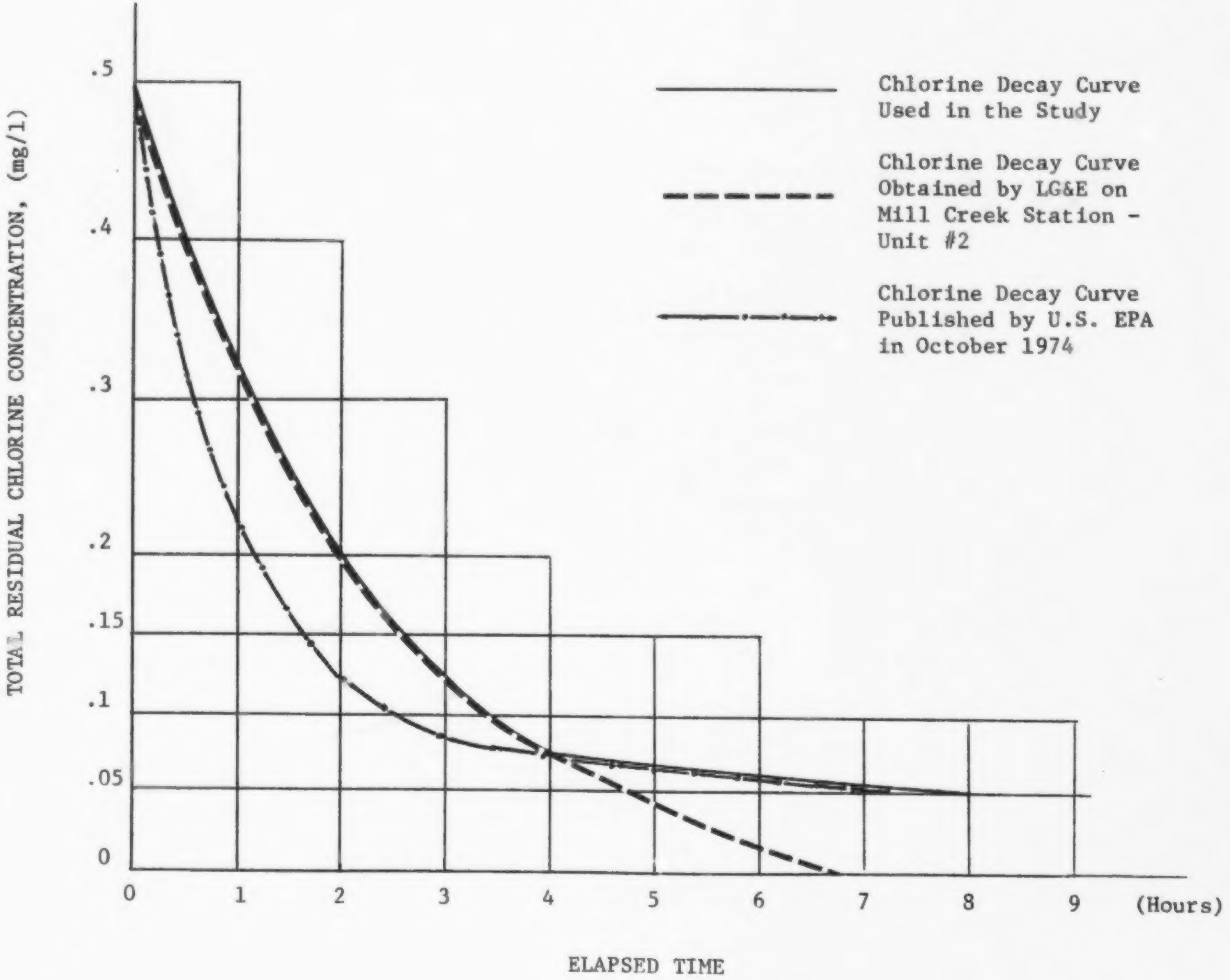

Chlorine Decay Curve Used in the Study
Chlorine Decay Curve Obtained by LG&E on Mill Creek Station - Unit #2
Chlorine Decay Curve Published by U.S. EPA in October 1974
TOTAL RESIDUAL CHLORINE CONCENTRATION, (mg/l)
.5
.4
.3
.2
.15
.1
.05
0
0
1
2
3
4
5
6
7
8
9
(Hours)
ELAPSED TIME

Fig. 6-3

VII SELECTION OF DISCHARGE STRUCTURE

Four possible discharge methods, as listed below, were analyzed:

1. Discharging to a local stream tributary to the river.
2. Routing to a storage basin before discharging to the river.
3. Land application of the effluent.
4. Direct discharge to the Ohio River.

This study concluded that:

Discharging into a local stream tributary to the river is unfeasible because there are none in the immediate area that are large enough to handle the volume of blowdown without being seriously impacted.

Routing to a storage basin before discharging to the river, though conceivable, is not recommended. To reduce the chlorine to acceptable limitations, it would be necessary to hold up the discharge for at least one day before discharging to the river. This would require two compartments in the storage basin and alternate the discharge every other day to the compartments. At maximum discharge, the storage capacity of each compartment would require 180 acre feet of storage for a total capacity of 360 acre feet.

Land disposal would require too large an area; assuming the soil is capable of accepting an average application of two inches of effluent per week for volumes produced, an area of about 4,500 acres would be required under extreme operational conditions.

Therefore, direct discharge to the Ohio River is the preferred method.

This study investigated the several types of discharge structures by which direct discharge into the Ohio River is feasible. A brief description of the various alternative discharge structures analyzed follows:

A. Submerged Discharges

Round Pipe

This is a submerged round pipe (or pipes) with a diffuser on the discharge end that produces a jet discharge. The discharge velocity can be varied only by replacing the diffuser end with one of another size or by varying the flow. The resulting plume is a cone (or cones) of effluent water extending up from the bottom towards the surface.

Slotted Pipe

A submerged circular pipe resting on the bottom of the river with rectangular slots along the length of the exposed submerged portion of the pipe make up this discharge structure. Velocity of discharge is fixed for a given flow. The resulting plume is a "sheet" of effluent water rising from the bottom of the river.

Multiport Diffuser

A multiport diffuser is a circular pipe resting on the bottom of the river with circular nozzles discharging upwards in the downstream direction. The nozzles are equally spaced along the length of the diffuser pipe. The discharge velocity is dependent upon the nozzle size and the discharge flow. The resulting plume is a "sheet" of effluent water, which in reality is a number of small cones rising from the bottom of the river.

B. Surface Discharges

Channel

A three-sided open channel is the simplest type of discharge structure. The discharge velocity is dependent upon the configuration of the channel and the amount of discharge and cannot be varied once the channel is constructed. The configuration of the plume is cone-shaped with very little depth.

Round Pipe

This alternate consists of a round or rectangular pipe (or pipes) possibly with a diffuser on the discharge end. For a given rate of flow, the discharge velocity is a fixed value, dependent on the diameter of the outlet or outlets. The resulting configuration is a cone-shaped plume.

Skimmer Wall

The skimmer wall discharge structure is a concrete structure with several steel gates, allowing the blowdown to be discharged to the receiving body. The discharge velocity is regulated by the number of gates open. One gate is normally in the open position. The discharge velocity is increased by opening one or more of the other gates. The resulting plume takes a "sheet" configuration, but is dependent upon the number of gates being utilized.

Spillway Outfall

The spillway outfall uses a discharge channel or tunnel with a flared outfall at the end. The flared outfall has a number of flow dividers that proportionally spreads the discharge over a wider area than would be obtained using only a channel or tunnel type of structure. For a given flow, the discharge velocity is a fixed quantity according to the angle of the flared outfall. The resulting plume takes a "sheet" configuration.

The surface discharge structures were evaluated for environmental compatability, economics, ease of maintenance, and the ability to perform and adapt to a wide range of operational conditions and requirements.

In the final analysis, a variation of the surface discharge round pipe and diffuser structure was selected. Some of the determining factors in this analysis included:

1. Versatility and ability to produce a minimal plume centerline length under fluctuating operational conditions.
2. Reliability and ease of maintenance.
3. Relatively low installed cost.

VIII COMPUTER ANALYSIS AND RESULTS

This study dealt with seven cases, representing the following conditions:

a. The four seasons average river conditions and discharge conditions.

b. Ten percental frequency low flow of the Ohio River for average summer and winter operating and river conditions.

c. The seven-day, 10-year low flow condition, with normal plant operational conditions.

The data used in the analysis of the "worst expected case" runs are presented in Table 8-2. The data and results for all operational and river conditions that were run can be reviewed in Appendix B, "PDS Run Results." (On file at EPA Region IV office.)

The data required to simulate the Ohio River condition during the above cases were obtained from the ORSANCO, and the Army Corps of Engineers Publications. The data needed to describe the plant blowdown were generated by Fluor Pioneer Inc.

The computer model output used to define the plume mixing zone area and dimensions is shown in Table 8-3 and illustrated in Figures 8-4 through 8-11.

From Table 8-3, for the four cases representing the average seasonal discharge condition, the 1/20 mixing for both thermal and chlorine discharges was achieved within 70 feet of centerline plume distance and 40 feet from the point of discharge in direction of the river width. These results were achieved by using discharge velocities between 5 fps and 20 fps. To obtain such velocities, the average seasonal blowdown (which is in a range from about 2,000 gpm to 5,000 gpm) was simulated, to be discharged through a single rectangular port measuring .45 ft. x .94 ft. at a 60° angle to the river flow.

The 10 percental river low flow for both the summer and winter condition was included in this study to examine the plume characteristic when the river velocity and flow are reduced significantly. The volume of the blowdown examined in these two cases was 2,180 gpm for both summer and winter conditions, with a temperature differential of 13°F, and 17°F for summer and winter conditions, respectively. Using a single rectangular port discharge configuration, the 1/20 mixing boundaries were achieved within a distance of 70 feet along the plume centerline and did not exceed 40 feet for either the river dimensions X and Y, as shown in Table 8-3, and in Figures 8-8 and 8-9.

The seven-day, 10-year low flow condition was included to evaluate the impact of the plant's normal operating condition during abnormally low and slow river conditions. Under the "worst expected case" condition of two units blowing down, the 1/20 mixing boundaries were achieved within a distance of 60 feet of the plume centerline and did not exceed 40 feet for either river dimensions X or Y, as shown in Table 8-3 and Figure 8-10.

A second run using the seven-day, 10-year low flow condition was run using a minimal flow of 500 gpm. This case represented one unit on line at 60% capacity. Under this condition, the 1/20 mixing boundaries were achieved within a distance of 40 feet of plume centerline and did not exceed 40 feet for either river dimension X or Y as shown in Table 8-3 and figure 8-11.

Table 8-3 also lists the plume depth for the eight cases studied. The deepest expected plume depth was 24 feet which only occurs during the seven-day, 10-year low flow condition.

To summarize the above discussion, this study has considered the average seasonal condition of blowdown, as well as particular cases when blowdown reaches its maximum or minimum expected volume. (Refer to Appendix B.) It was determined that under these different operational conditions the 1/20 mixing needed for thermal and chlorine discharges was accomplished within reasonable distances from the point of discharge using a multiport discharge arrangement, all rectangular in shape.

TABLE 8-1

AMBIENT RIVER DATA USED FOR COMPUTER MODEL INPUT, WORST EXPECTED CASE

		River Data		
Case No.	Case Tested	Temperature (^{o}F)	Velocity At Discharge Point (fps)	Flow Rate (cfs) (gpm)
1	Average Winter Season	40.0	1.84	177,300 (7.5x10^7)
2	Average Spring Season	53.0	1.86	200,200 (9.0x10^7)
3	Average Summer Season	77.0	0.58	46,600 (2.1x10^7)
4	Average Fall Season	67.0	0.44	34,700 (1.5x10^7)
5	10 Percentile Low Flow Summer Season	73.3	.217	17,080 (0.8x10^7)
6	10 Percentile Low Flow Winter Season	38.8	.652	53,750 (2.4x10^7)
7	10-yr, 7-day Low Flow	73.3	0.18	14,200 (0.6x10^7)
8	10-yr, 7-day Low Flow 500 gpm	73.3	0.18	14,200 (0.6x10^7)

TABLE 8-2

PLANT OPERATING DATA AND AMBIENT AIR DATA USED FOR COMPUTER MODEL INPUT, WORST EXPECTED CASES

Case No.	Case Tested	Capacity Factor %	Ambient** Dry Bulb	Wet** Bulb	Relative Humidity %	No. of Units	Discharge Flow Rate*** (gpm)	Discharge Temperature (°F)	Cooling Tower No. of Cycles
1	Average Winter Season	100*	36.5	35.0	60	2	2180	55	5
2	Average Spring Season	100	60.0	51.0	52	2	2180	67	5
3	Average Summer Season	100	82.5	70.0	55	2	2180	86	5
4	Average Fall Season	100	63.5	55.0	58	2	2180	68	5
5	10 Percentile Low Flow Summer Season	100	82.5	70.0	55	2	2180	86	5
6	10 Percentaile Low Flow Winter Season	100	36.5	32.0	60	2	2180	55	5
7	10-yr, 7-day Low Flow Summer Season	100	82.5	70.0	55	2	2180	86	5
8	10-yr, 7-day Low Flow Summer Season - 500 gpm	60	82.5	70.0	55	1	500	91	5

* Valves wide open, 5% overpressure.

** Based on daily load following peak during daylight.

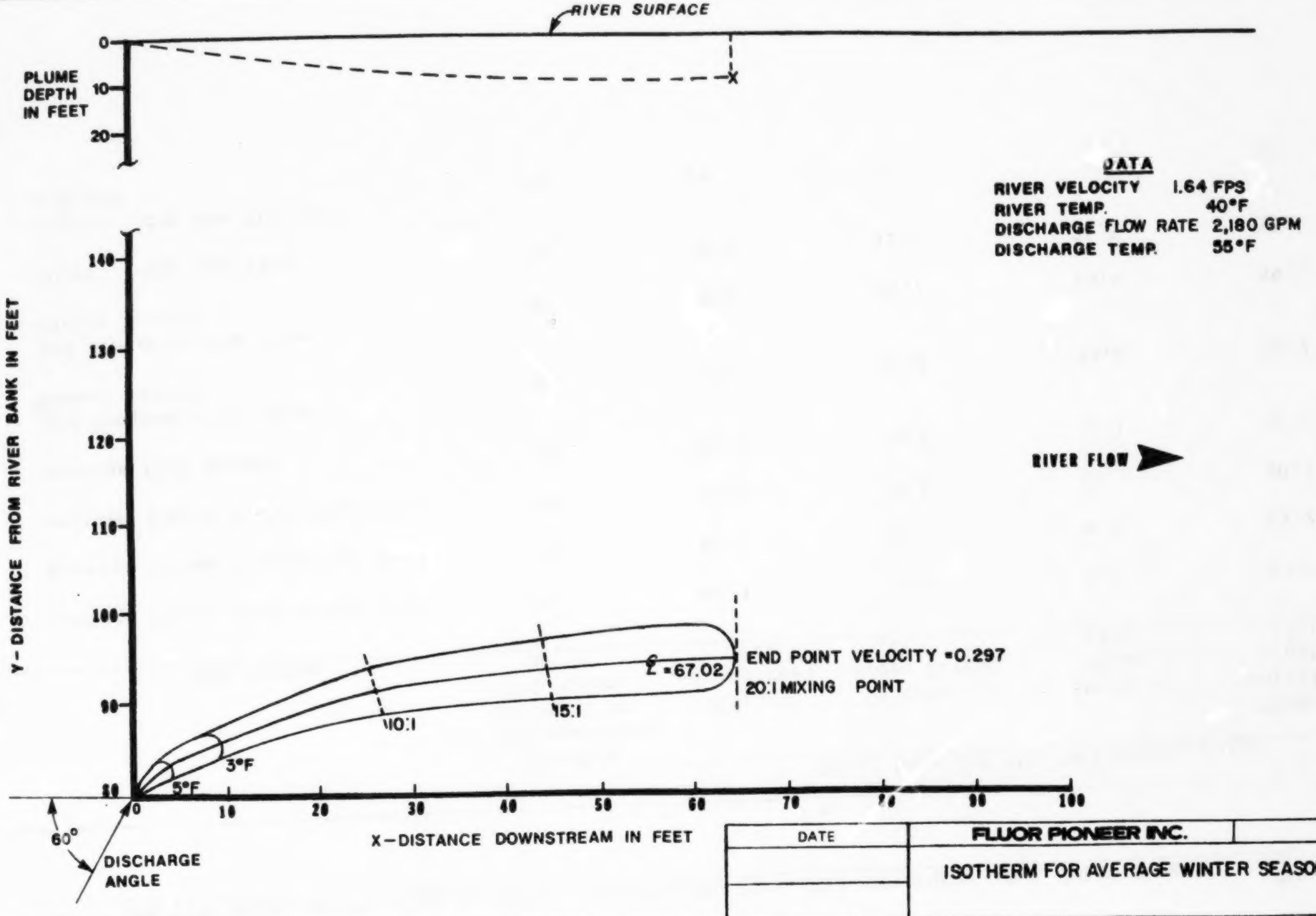
*** Not taking ambient air data into consideration for conservativeness.

Computer runs were made for 4 units, 3 units, 2 units and a single unit being in operation. The worst expected case occurs when 2 units are in operation.

TABLE 8-3

COMPUTER MODEL OUTPUT USED TO DEFINE PLUME MIXING ZONE AREA AND DIMENSIONS, WORST EXPECTED CASE

Case No.	Case Tested	Chlorine Concentration At Point of 20:1 Mixing (mg/1)	Plume Data for the 20:1 Mixing Point			
			Distance Downstream (ft)	Distance Cross Stream (ft)	Depth of Plume (ft)	Plume Centerline Length (ft)
1	Average Winter Season(Fig. 8-4)	.01	64.3	15.0	9.2	67.0
2	Average Spring Season(Fig. 8-5)	.01	66.7	14.1	9.2	69.2
3	Average Summer Season(Fig. 8-6)	.01	52.6	28.1	16.1	60.7
4	Average Fall Season	.01	46.3	29.5	15.1	55.9
5	10% Frequency Low Flow Summer Season	.01	42.4	39.8	23.4	58.7
6	10% Frequency Low Flow Winter Season	.01	52.4	25.7	13.9	59.4
7	10-yr, 7-day Low Flow	.01	40.6	41.4	24.5	58.4
8	10-yr, 7-day Low Flow at 500 gpm	.01	19	19	5.0	27



DATE	FLUOR PIONEER INC.	
	ISOTHERM FOR AVERAGE WINTER SEASON	SHT FIG. 8-4

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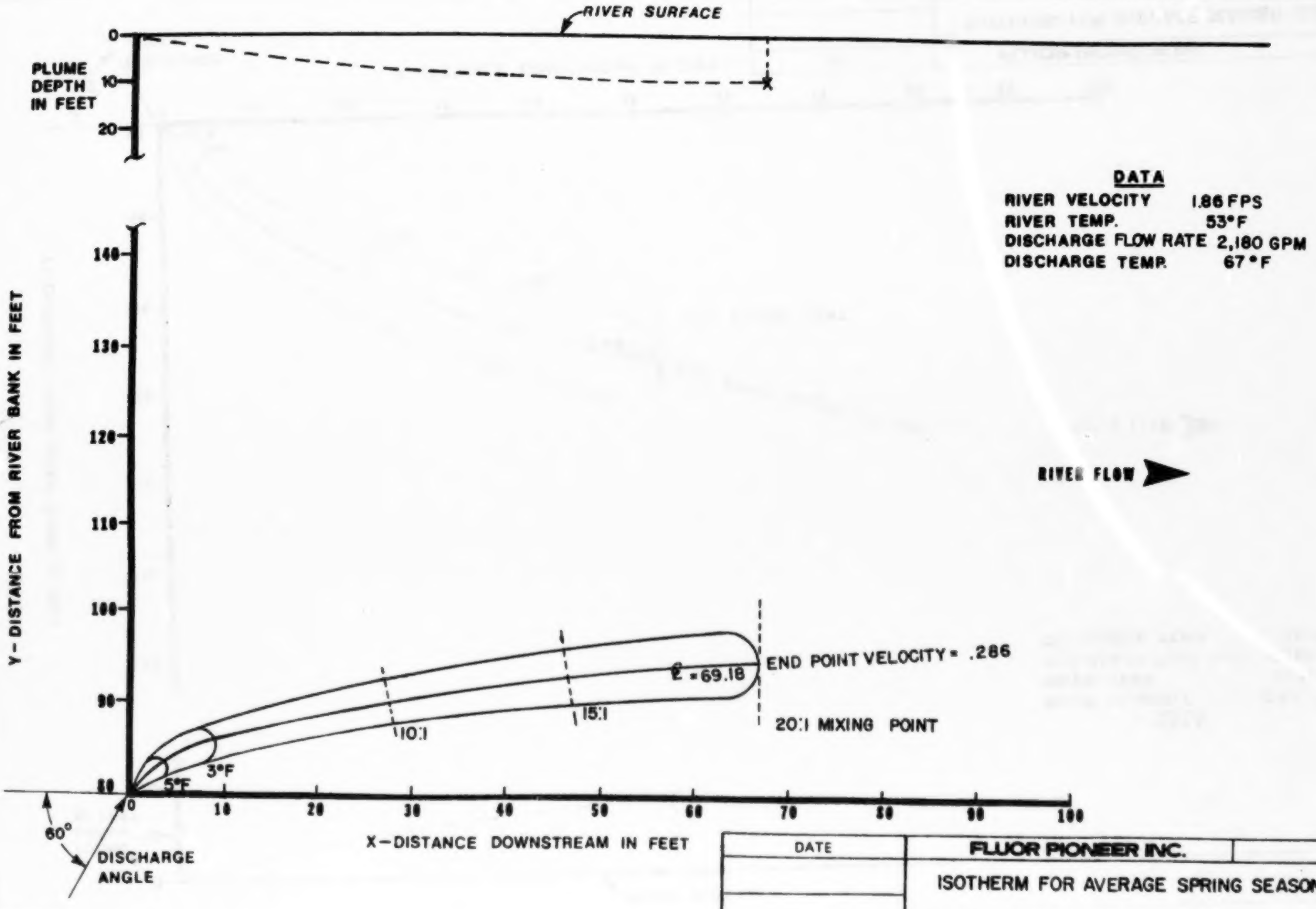

DATE	FLUOR PIONEER INC.	
	ISOTHERM FOR AVERAGE SPRING SEASON	SHT
		FIG.
		8-5

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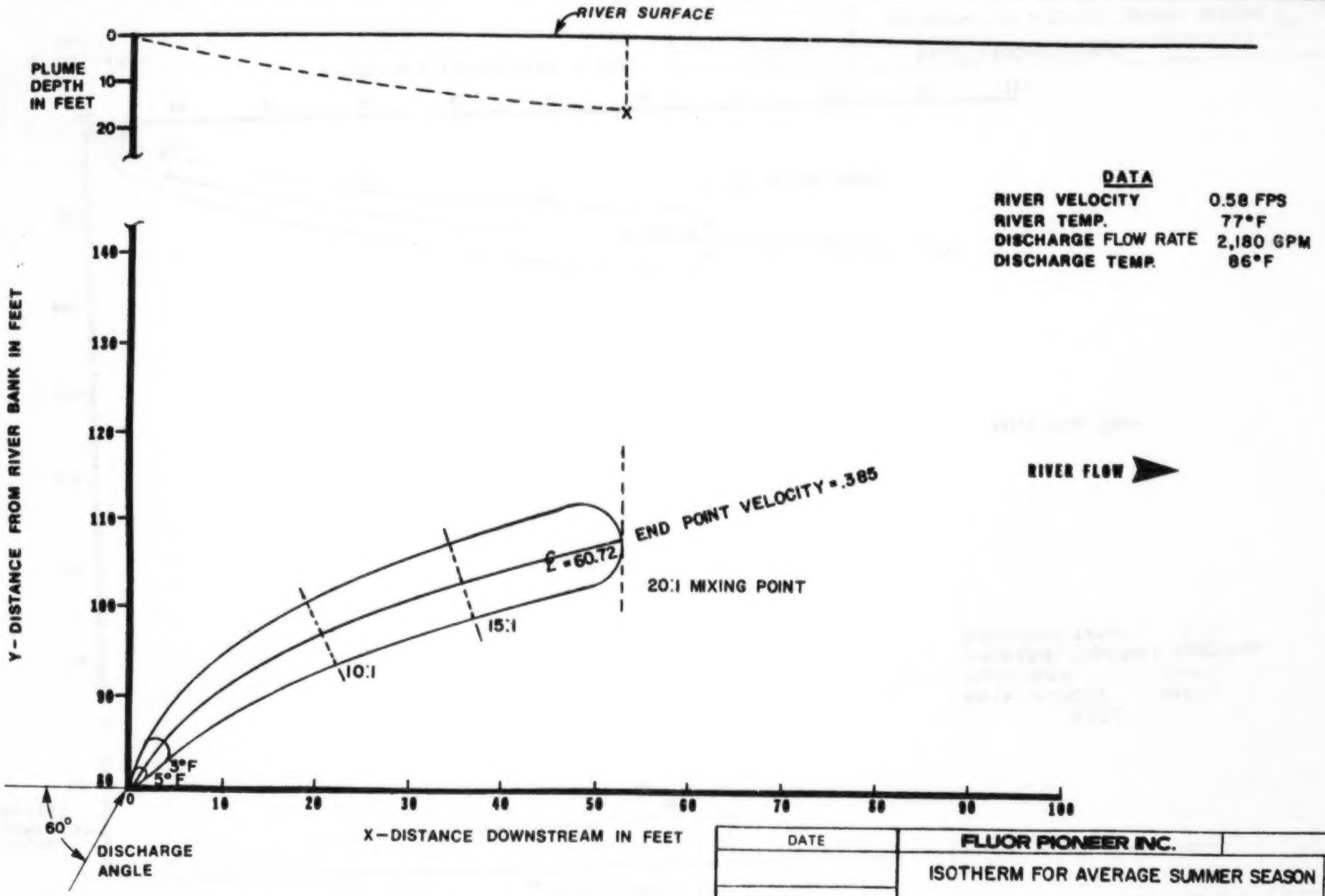

DATE	FLUOR PIONEER INC.	
	ISOTHERM FOR AVERAGE SUMMER SEASON	SHT
		FIG. 8-6

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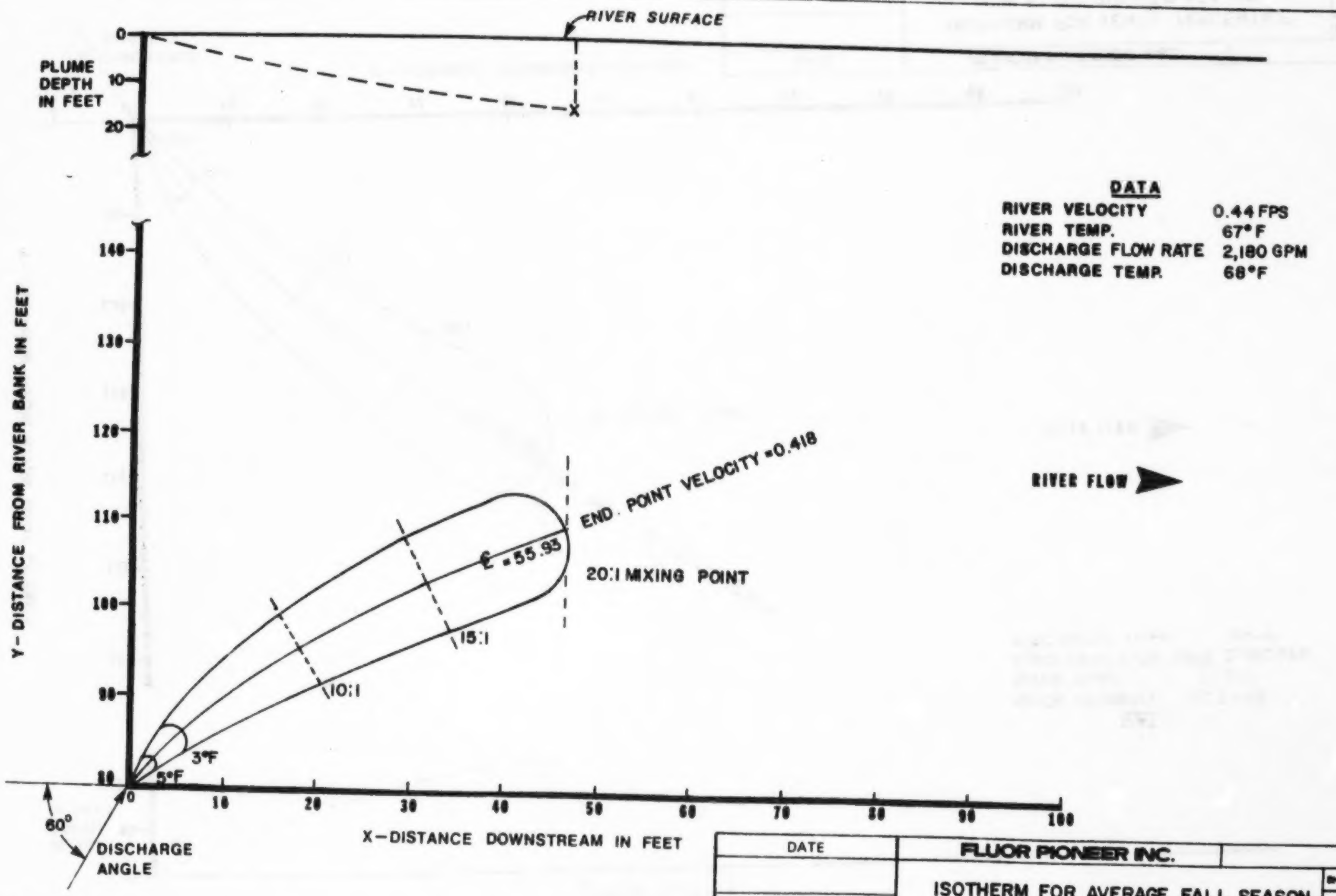
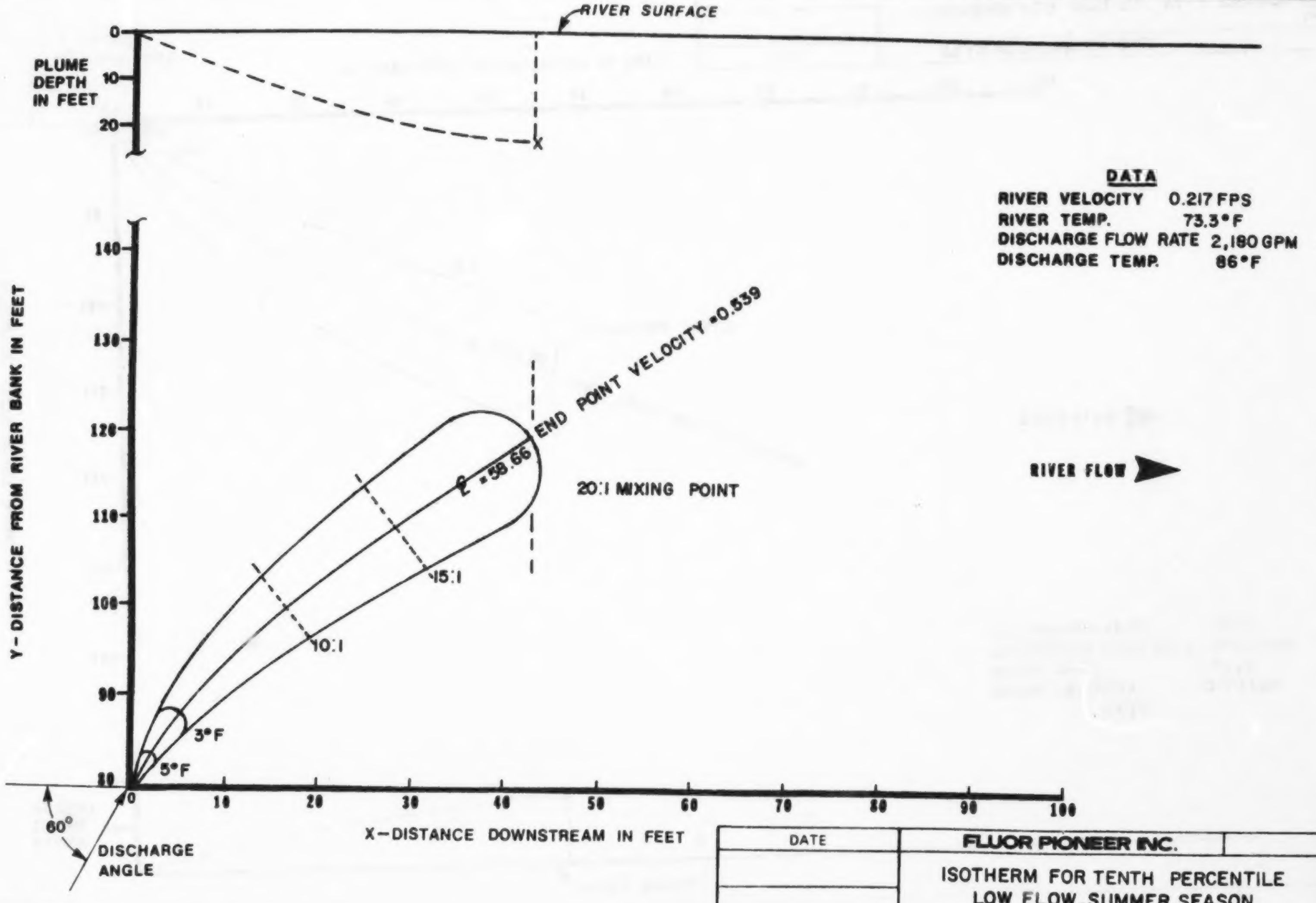


DATE	FLUOR PIONEER INC.	
	ISOTHERM FOR AVERAGE FALL SEASON	SHT
		FIG.
		8-7

Temp.Form C-312A 2/12/[illegible]



DATE

FLUOR PIONEER INC.

ISOTHERM FOR TENTH PERCENTILE
LOW FLOW, SUMMER SEASON

FIG.
8-8

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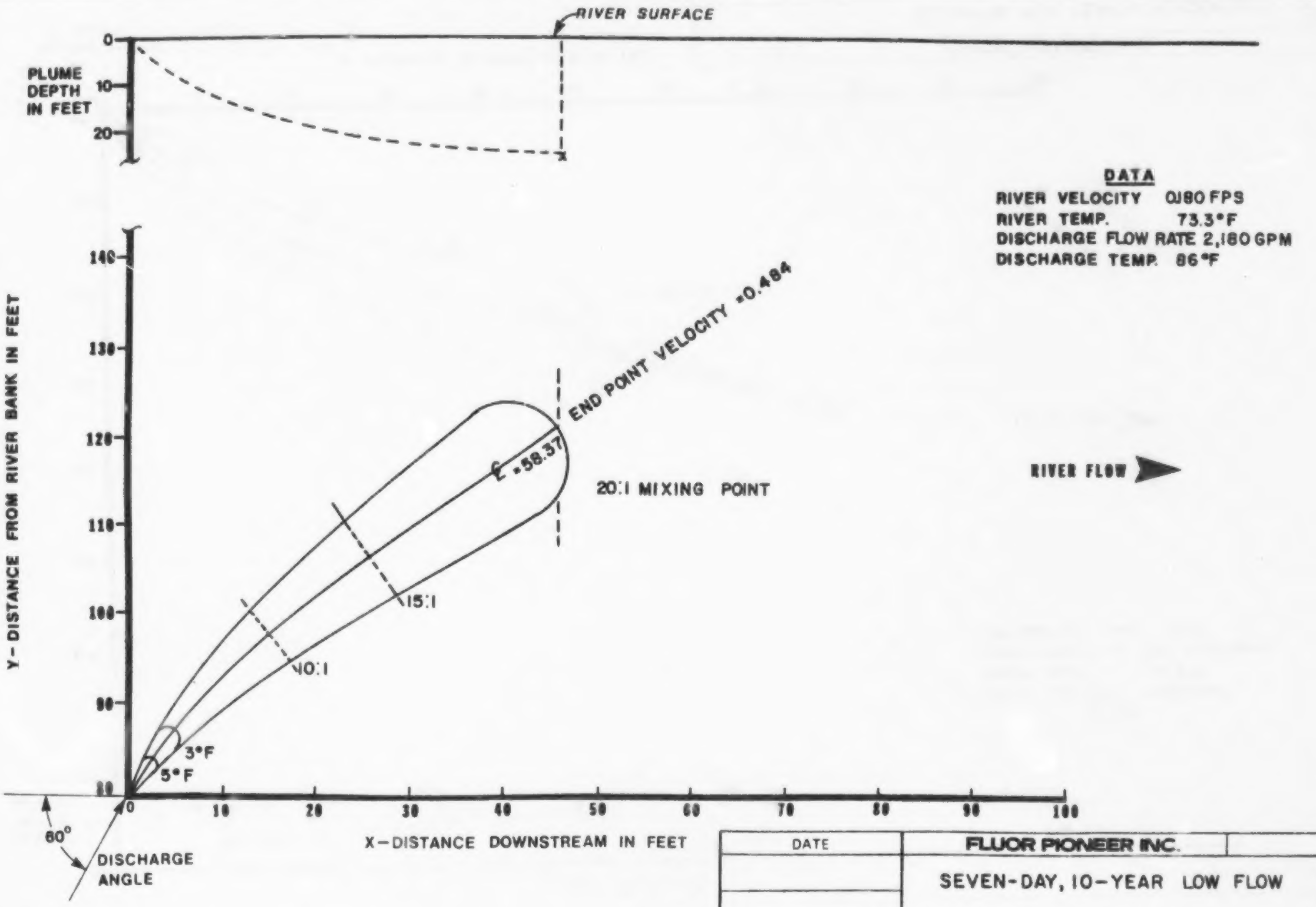
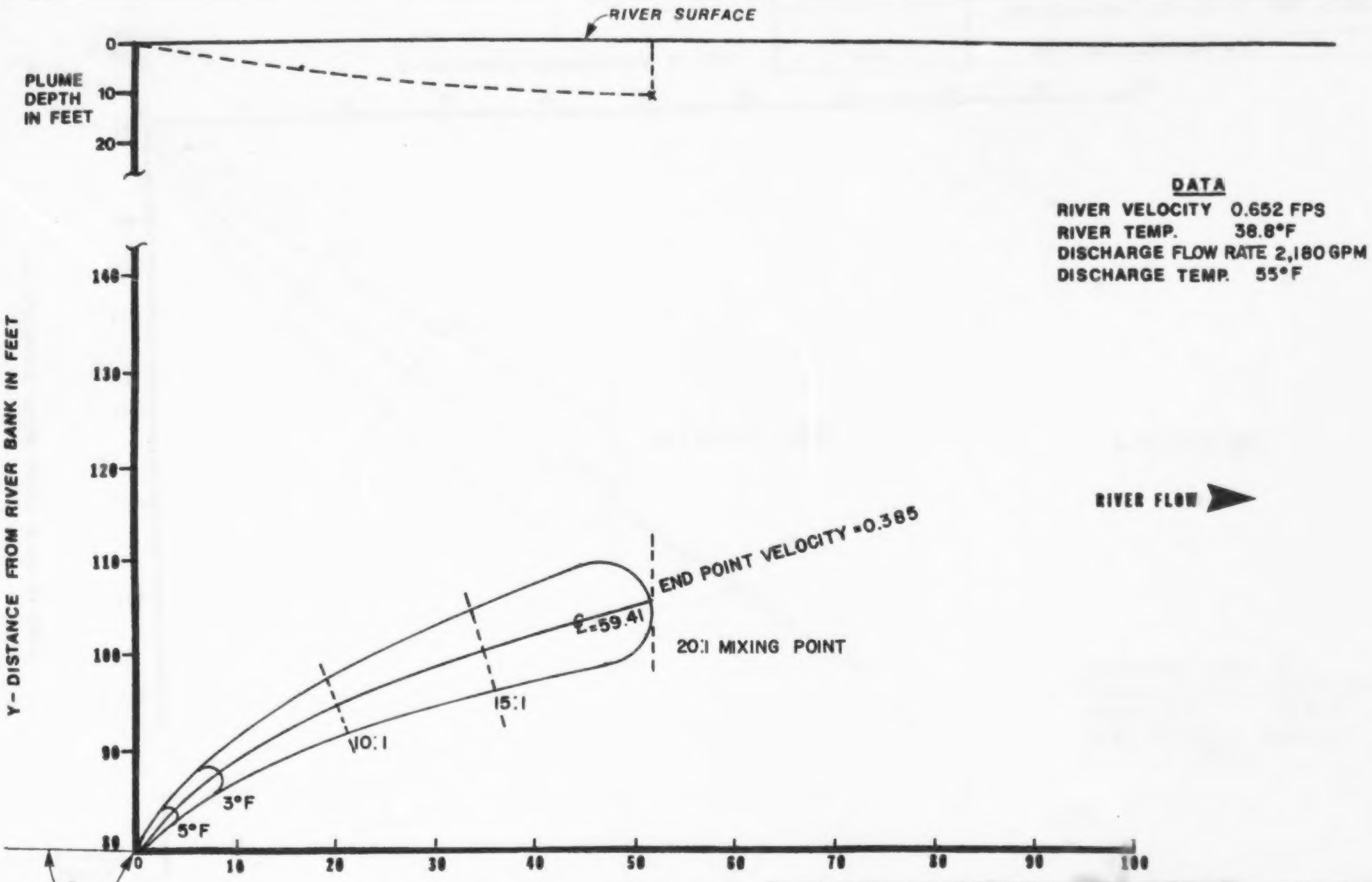


DATE	FLUOR PIONEER INC.	
	SEVEN-DAY, 10-YEAR LOW FLOW	SHT FIG. 8-9

Temp. Form C-312A



8-12

DATE	FLUO[illegible]IONEER INC.	
	ISOTHERM FOR TENTH PERCENTILE LOW FLOW, WINTER SEASON	SHT FIG. 8-10

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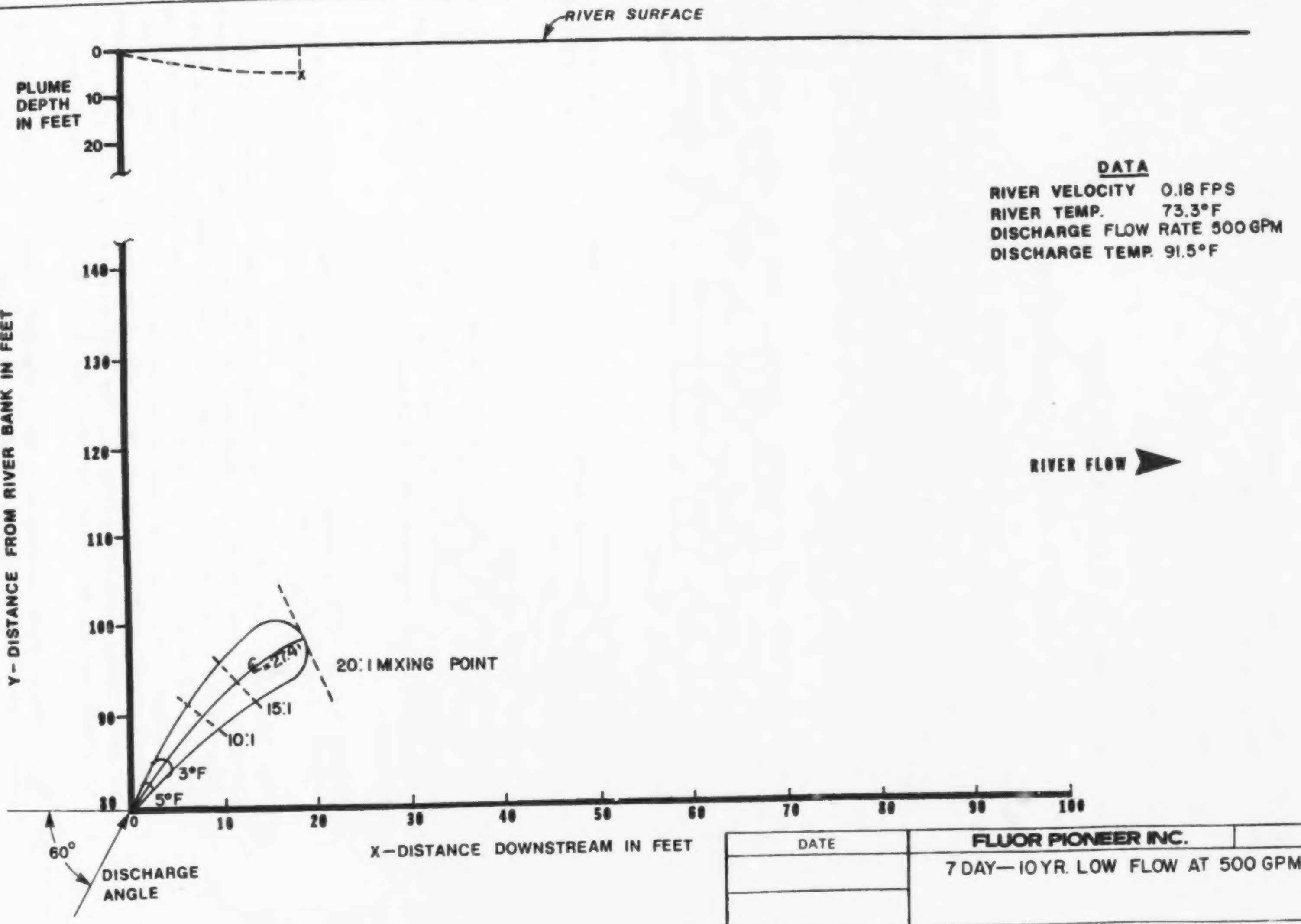

DATE	FLUOR PIONEER INC.	
	7 DAY— 10 YR. LOW FLOW AT 500 GPM	SHT FIG. 8-11

IX ENVIRONMENTAL EFFECT OF DISCHARGE

The discharge of the cooling tower blowdown into the Ohio River can affect the following areas of concern:

a) Interference with river traffic

b) Scouring of river bottom

c) Excess heat in the discharged water

d) High total residual chlorine concentrations

Offshore river velocities at the outlet shown in Table 8-1 are estimated to be from .18 to two feet per second. The unloading facilities and the frequent barge traffic can be expected to reduce river velocities between the mooring cells and the shore at the outlet shown in Figure 2-2. It is not likely that discharge flow will interfere with barge operations. Assuming a 20 feet per second discharge velocity and a 150 feet distance to the nearest barge, the velocity of crosscurrent flow will not exceed two to three feet per second.

To minimize scouring, the discharge structure will be angled 15°F from the horizontal plane. This will direct the jet upward, away from the river bottom, and will decrease the contact with the bed. Riprap also will be placed in front of the discharge nozzles to abate scouring. These measures then will result in minimal scouring of the bed immediately downstream along the plume.

The last two areas of possible concern - excess heat in the discharged water and high total residual chlorine concentrations - are interrelated and will be discussed as one.

As can be seen from figures 8-4 through 8-11, the plumes produced by the plant are neither exceptionally wide nor long, especially when compared to the width and length of the Ohio River at the point of discharge. Further the following points testify to the fact that the results demonstrated in the aforementioned figures and in Appendix B, PDS run results are conservative:

a) There is no credit taken for a chlorine demand existing in the river, and in fact, the chlorine demand is relatively high.

b) The PDS model calculates concentrations from an outfall on the surface or just below the surface of the receiving body of water. It does not, therefore, calculate any entrainment of ambient water on the top surface of the plume. In this instance, however, the discharge structure is located in at least 10 feet of water (at normal pool) and is located two feet from the bottom. The plume then is entraining ambient water on the top surface of the plume until it rises enough to reach the surface some distance downstream.

c) The conduit that transports the blowdown water from the cooling towers to the discharge structure is buried for approximately one mile. This will have an effect on the effluent in two ways:

(1) it will decrease the temperature of the effluent water; and (2) it will give the chlorine an opportunity to react further and thus lower its concentration in the effluent stream.

d) The inherent conservativeness of the model when assuming equal distribution of chemicals within the plume, in relation to the velocity distribution in the plume, as reported by Shirazi.

e) The plume centerline length for the 20:1 mixing ratio was calculated using the thermal distribution in the plume which is a more conservative assumption than using the velocity distribution in the plume.

f) The maximum blowdown value at five (5) cycles of concentration was maintained at a constant for all seasons as a measure of conservancy.

Furthermore it is felt that:

Discharge away from the shoreline will help provide access for ambient water around the entire periphery of the thermal plume and improve dispersion no matter what wind or total conditions exist.

The criteria utilized to set the existing chlorine standards are appropriate only to continuous chlorination situation, and as seen in Section VI - Chlorination Schemes, this plant only utilizes intermittent chlorination schemes.

The relationship between the total blowdown under worst expected conditions, and the amount of water in the Ohio River at the point of discharge is about 1 to 10,000 with a chlorine concentration of approximately .2 mg/l in the discharged water.

We can assume an exceptionally minimal amount of environmental impact to the river and its biota from the discharge of the cooling tower blowdown and the manner in which this blowdown will be dispersed.

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